THE HAWAIIAN PLANTERS' RECORD

Vol. XXXVI SECOND QUARTER, 1932 No. 2

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Changes in Cane Quality:

Data on cane quality of the different plantations over a series of years are presented in compact form in an arrangement that admits of ready comparisons.

Corn Oil for Thallium Wheat Torpedoes:

This paper gives the details of a series of small experiments to determine the desirability of corn oil to make thallium wheat torpedoes more attractive to rats.

Rats showed a decided preference for corn oil over sunflower oil, coconut oil, or paraffine as a material to saturate the paper torpedoes.

In a test at Kailua, about three corn-oiled torpedoes were taken to each paraffine-dipped torpedo.

It was found that the torpedoes continued to be attractive when they were dipped in a mixture of one part of corn oil to three parts of paraffine by weight. This treatment offers the best practical method of combining corn oil with paraffine for waterproofing thallium wheat torpedoes.

Distribution of Soil Moisture Under the Border Method of Irrigation:

Further investigations on the lateral and vertical penetration of soil moisture under the border method of irrigation at the Ewa Plantation Company are reported in this issue. The results indicate the effect of ground slope and the amount of surface application on the subsequent distribution of soil moisture.

Forest Insects on Hawaii:

Mr. Swezey gives an important detailed account of the insects found on or associated with the living, dying and dead native trees of a portion of the large belt of windward Hawaii which has never been previously explored for insects.

Of particular interest are the observations on the insects attached to the dying and dead koa trees. These insects only begin their attacks after the trees or branches are dead or dying from other causes. A superficial conclusion that the insects were the original cause of this condition is usually reached by uninformed persons.

Leaf Scald Disease of Sugar Cane in Hawaii:

This paper records a study of leaf scald disease as it occurs locally. This disease, which has caused significant losses to the sugar industry of Java and Australia, particularly through the elimination of desirable varieties, appears to have been present in obscure form in the Islands for several years. On certain of the Hawaiian varieties, particularly of the Manoa series, unmistakable symptoms occur which permit identification of the disease. Two forms of the disease, the chronic and the acute, occur, the symptoms of which are detailed and illustrated to facilitate identification of the disease.

Of the eight more important cane diseases described in the literature, leaf scald and mosaic are the only two now known to occur in Hawaii.

Among the subjects presented are the following: Geographical distribution, nature of the causal bacterium, results of inoculation experiments, histology, varieties affected and resistance of varieties, mode of transmission and control.

Leaf scald disease seriously impairs the value of the more susceptible cane varieties, but thus far it has been almost entirely confined to test plots of locally developed varieties and appears to be of minor importance to the sugar industry of Hawaii. Its potential significance in relation to present and future commercial cane varieties is not to be underestimated.

Study of Correlation Between Cane Yields and Quality Ratio of Irrigated Cane:

A study of the correlation between the cane yields and the quality ratio of irrigated cane, made from a series of experiments that have been conducted over a period of six years at Waialua Agricultural Company and the Waipio substation, indicates that direct cause and effect relations between these two factors have not been definitely established.

Dwarf Disease of Sugar Cane:

An illustrated article by Arthur F. Bell, pathologist of the Bureau of Sugar Experiment Stations, Queensland, describing this new disease of cane in the Mackay district, is reprinted in full. This apparently serious disease of the variety P. O. J. 2714 has features in common with Fiji, sereh and streak diseases. The origin and cause of dwarf disease have not been determined.

The Cane-Killing Weed:

Arthur F. Bell and W. Cottrell-Dormer, of the Bureau of Sugar Experiment Stations, Queensland, recount the history and distribution of three distinct species of parasitic weeds of the genus Striga, in a paper reprinted under the above title. These weeds are annuals which are propagated by small, light seeds, easily carried by the wind and by the drainage and irrigation water. They are not known to be present in Hawaii. As a rule the areas of cane affected are roughly circular in shape, with a diameter of a few yards. The damage ranges from a barely perceptible stunting to a premature death of the cane.

Changes in Cane Quality

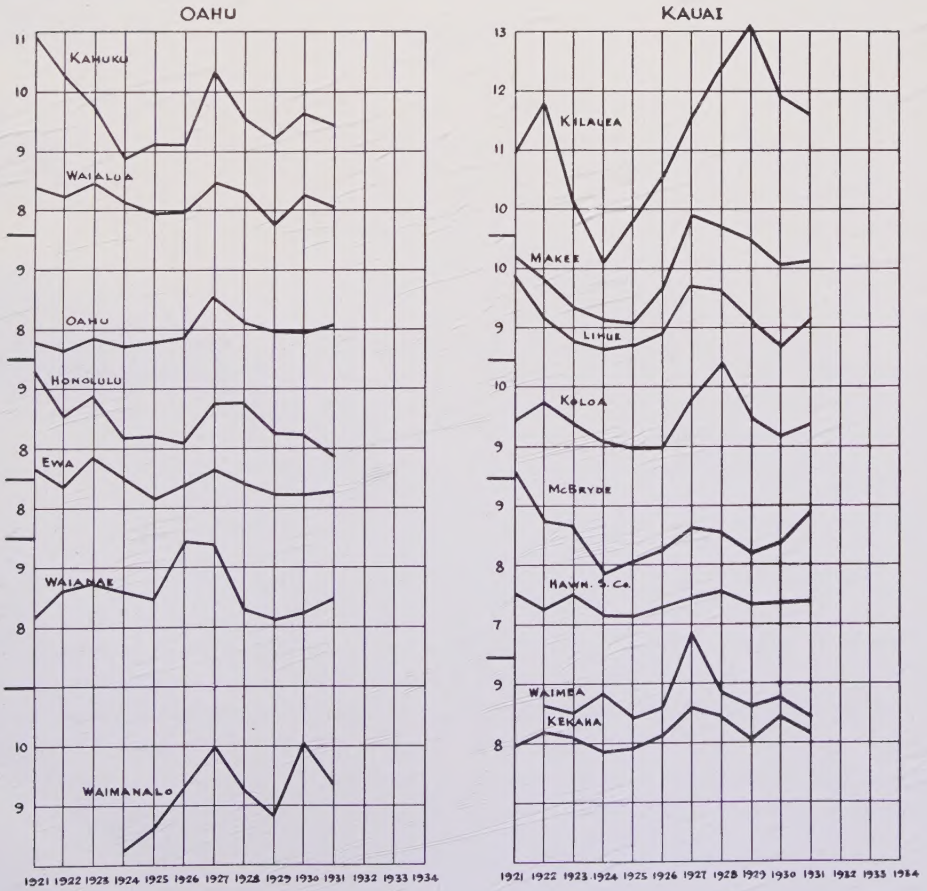
By Ralph J. Borden

The accompanying illustrations, showing the tons of cane per ton of commercial sugar, are made up from the data in the official mill reports of plantations, 1924 to 1931, inclusive. The arrangement, in approximate geographical order, offers a most interesting study. A table showing the changes that took place at each plantation over a ten-year period is also offered.

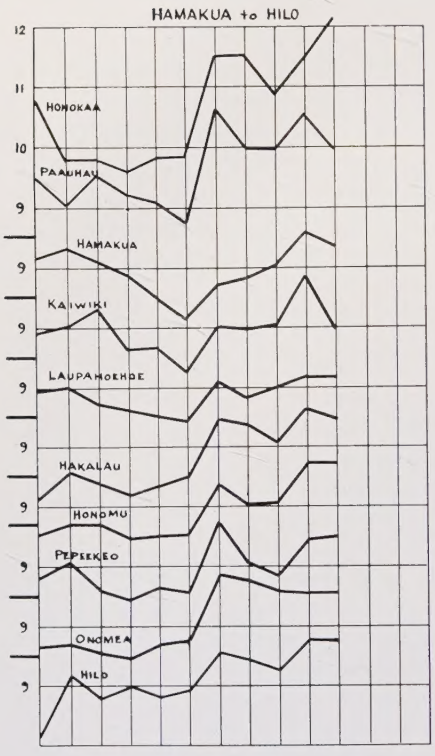
Consideration of the many varietal, cultural, and other differences that exist on the plantations, makes it appear that some other factor, perhaps weather, has been the controlling influence on cane quality. Exceptions to the general trend in any one year are evident and inveigle one's curiosity to know what factors in such exceptional cases may have assisted or antagonized the weather in its effect on cane quality.

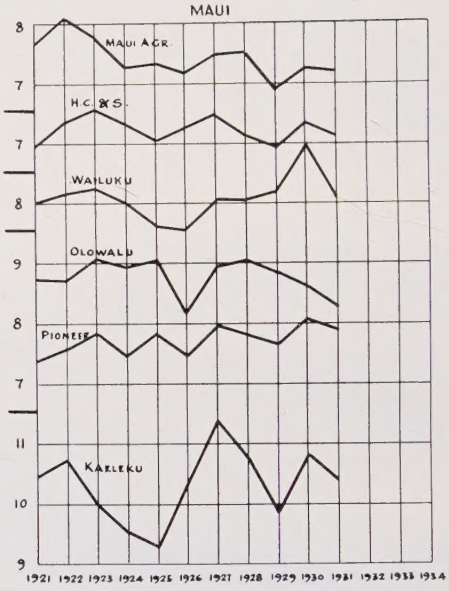
TC/TS FOR ALL PLANTATIONS - CROPS 1921-1931 (incl.)

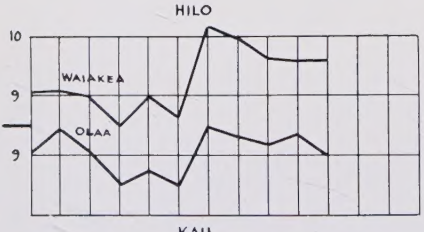
ARRANGED BY GEOGRAPHICAL DISTRICTS

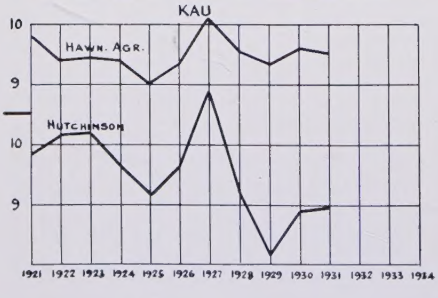


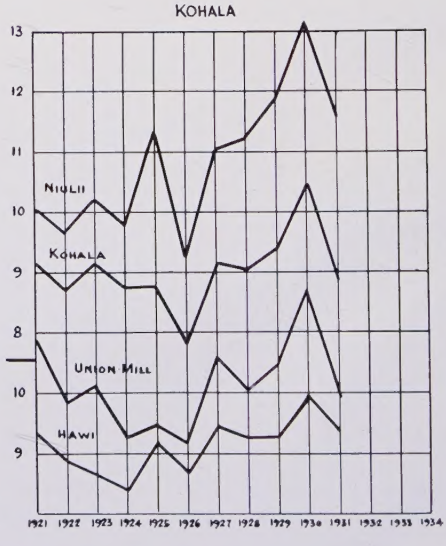
TC/TS FOR ALL PLANTATIONS - CROPS 1921 - 1931 Incl.)
ARRANGED BY GEOGRAPHICAL DISTRICTS











CHANGES IN CANE QUALITY

Better (+) or Poorer (—) Juices and TC/TS Amount of Difference Between Consecutive Years

Plantation	Between the Years 1921 and 1922	1922 and 1923	1923 and 1924	1924 and 1925	1925 and 1926	1926 and 1927	1927 and 1928	1928 and 1929	1929 and 1930	1930 and 1931
Niulii	+ .4	— .6	+ .5	—1.7	+2.2	—1.9	— .1	— .7	—1.3	+1.6
Kohala	+ .5	— .5	+ .4	— .1	+1.0	—1.4	+ .1	— .3	—1.0	+1.6
Union	+1.1	— .3	+ .9	— .3	+ .3	—1.4	+ .6	— .5	—1.2	+1.8
Hawi	+ .5	+ .2	+ .3	— .8	+ .6	— .8	+ .4	0	— .6	+ .6
Honokaa	+1.1	0	+ .2	— .3	0	—1.7	0	+ .7	— .6	— .7
Paauhau	+ .5	— .5	+ .3	+ .1	+ .4	—1.9	+ .7	0	— .6	+ .6
Hamakua	— .2	+ .2	+ .2	+ .4	+ .4	— .6	— .1	— .2	— .6	+ .2
Kaiwiki	0	— .3	+ .7	— .1	+ .5	— .8	+ .1	— .1	— .8	+ .9
Laupahoehoe	0	+ .3	+ .1	+ .1	+ .1	— .7	+ .3	+ .2	— .2	0
Hakalau	— .4	+ .2	+ .1	— .1	— .2	—1.0	+ .1	+ .4	— .6	+ .2
Honomu	— .3	+ .1	+ .2	0	0	— .9	+ .4	0	— .7	+ .1
Pepeekeo	— .3	+ .6	+ .1	— .2	+ .1	—1.2	+ .6	+ .1	— .6	0
Onomea	— .1	+ .2	+ .1	— .2	— .1	—1.1	0	+ .2	0	0
Hilo	—1.1	+ .5	— .2	+ .2	— .1	— .7	+ .1	+ .2	— .6	+ .1
Waiakea	0	+ .1	+ .5	— .5	+ .4	—1.6	+ .3	+ .3	+ .1	0
Olaa	— .4	+ .5	+ .5	— .2	+ .2	—1.0	+ .2	+ .1	— .2	+ .4
Hawn. Agri.	+ .5	— .1	+ .1	+ .4	— .4	— .7	+ .5	+ .2	— .2	+ .1
Hutchinson	— .3	— .1	+ .7	+ .4	— .4	—1.3	+1.7	+1.1	— .7	— .1
Kaeleku	— .3	+ .8	+ .5	+ .2	—1.1	—1.0	+ .7	+ .9	—1.0	+ .5
Maui Agri.	— .5	+ .3	+ .5	— .1	+ .2	— .3	— .1	+ .6	— .3	0
H. C. & S.	— .4	— .2	+ .2	+ .3	— .2	— .2	+ .3	+ .2	— .5	+ .2
Wailuku	— .2	— .2	+ .2	+ .4	+ .1	— .6	+ .1	— .2	— .8	+1.0
Olowalu	0	— .4	+ .2	— .2	+ .9	— .7	— .1	+ .1	+ .3	+ .3
Pioneer	— .2	— .2	+ .3	— .4	+ .4	— .5	+ .2	+ .2	— .4	+ .2
Kahuku	+ .6	+ .6	+ .9	— .2	0	—1.2	+ .7	+ .4	— .5	+ .2
Waialua	+ .2	— .2	+ .3	+ .2	0	— .5	+ .2	+ .6	— .6	+ .3
Ewa	+ .3	— .5	+ .3	+ .4	— .2	— .2	+ .2	+ .2	0	— .1
Waianae	— .5	— .1	+ .1	+ .2	—1.0	+ .1	+1.1	+ .2	— .1	— .2
Oahu	+ .1	— .2	+ .2	— .1	— .1	— .7	+ .4	+ .1	+ .1	— .1
Honolulu	+ .8	— .4	+ .7	— .1	+ .2	— .7	0	+ .5	+ .1	+ .3
Waimanalo	— .3	.....	.....	— .4	— .7	— .7	+ .8	+ .4	—1.2	+ .7
Kilauea	— .8	+1.7	+1.0	— .7	— .7	—1.0	— .9	— .7	+2.2	+ .2
Makee	— .4	+ .5	+ .2	0	— .6	—1.2	+ .2	+ .2	+ .4	— .1
Lihue	— .8	+ .4	+ .2	— .1	— .2	— .8	+ .1	+ .5	+ .4	— .5
Koloa	— .3	+ .4	+ .3	+ .1	0	— .8	— .6	+ .9	+ .3	— .2
McBryde	+ .9	+ .1	+ .7	— .1	— .2	— .4	+ .1	+ .4	— .1	— .6
Hawn. Sugar	+ .3	— .3	+ .3	0	— .2	— .2	— .1	+ .3	— .1	0
Waimea	.....	+ .1	— .4	+ .5	— .2	—1.3	+1.0	+ .2	— .1	+ .2
Kekaha	— .3	+ .1	+ .2	— .1	— .2	— .5	+ .1	+ .5	— .4	+ .2

Digitized by the Internet Archive
in 2025

https://archive.org/details/hawaiian-planters-record_1932_36_2

The Use of Corn Oil for Thallium Wheat Torpedoes

By R. E. Doty

The thallium wheat torpedoes, as developed and reported by C. C. Barnum, appear to be an excellent means of poisoning rats. It is highly desirable, therefore, that these torpedoes be made more attractive.

With this in mind, Dr. A. J. Mangelsdorf suggested to the writer that certain vegetable oils be tried out as waterproofing materials for the torpedoes with the hope that the odors of the several oils might prove a special attraction to the rats.

Experiments were carried out from time to time at Kailua and the results tabulated.

Corn Oil, Sunflower Oil, Cocoanut Oil, Versus Paraffine Torpedoes, When Placed Together in Stations

Experiment 1-A:

This experiment was planned to determine the preference of rats for corn oil, sunflower oil, cocoanut oil, and paraffine when used to saturate the fibre spun wrapper to make the thallium wheat more attractive.

Three torpedoes of each kind were placed in groups or stations scattered at intervals of 15 to 25 feet along the edge of various fields of big cane at Kailua substation. Each station was staked and numbered for reference in tabulating the results. These stations were visited every day for three days and those torpedoes taken were replaced.

The results from 61 stations, representing a total of 420 torpedoes of each kind exposed for a period of 24 hours, are tabulated below:

	Corn Oil				Sunflower Oil			
	November			Total	November			Total
	13	14	15		13	14	15	
Total torpedoes put out	54	183	183	420	54	183	183	420
Number torpedoes taken	41	124	95	260	35	77	61	173
Per cent taken	75.9	67.8	52.0	**61.9**	64.8	42.1	33.3	**41.2**

	Cocoanut Oil				Paraffine Oil			
	November			Total	November			Total
	13	14	15		13	14	15	
Total torpedoes put out	54	183	183	420	54	183	183	420
Number torpedoes taken	37	72	55	164	4	14	26	44
Per cent taken	68.5	39.3	30.1	**39.0**	7.4	7.6	14.2	**10.5**

This test showed that corn oil was preferred, the rats having taken 61.9 per cent of the corn oil, 41.2 per cent of the sunflower oil, 39 per cent of the cocoanut oil, and only 10.5 per cent of the paraffine-dipped torpedoes. These results are presented graphically in Fig. 1.

EXPERIMENT 1-A

Graph Showing Successive Daily Preference Of Rats For The Different Kinds Of Torpedoes.

3 Torpedoes of each Kind at each station.

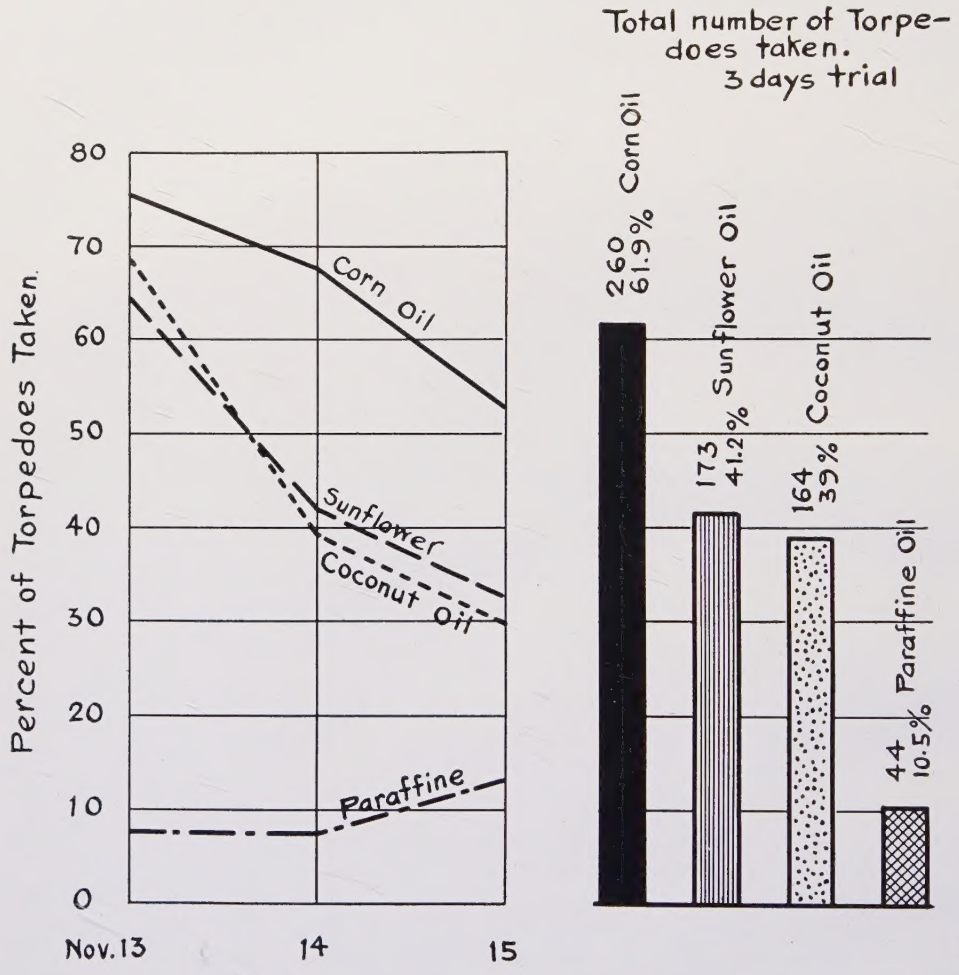


FIG. 1.

Experiment 1-B:

This test was undertaken as a duplicate of Experiment 1-A except that the number of each kind of torpedo was reduced to two.

The stations were visited daily for six days and the results tabulated.

This summary represents a total of 854 torpedoes of each kind exposed for at least 24 hours.

SUMMARY OF DATA COLLECTED IN FIELD L, KAILUA SUBSTATION

(2 torpedoes of each kind placed in each station each time they needed to be refilled)

CORN OIL

	Dates Put Out—December						Grand
	2	3	4	5	6	8	Total
No. of days after start of experiment	1	2	3	4	5	7	
No. of stations represented	64	64	76	76	76	71	427
Total number of torpedoes represented	128	128	152	152	152	142	854
No. of torpedoes taken	34	60	79	44	67	80	364
Per cent taken	26.6	46.9	52.0	28.9	44.1	56.3	**42.6**

SUNFLOWER OIL

	Dates Put Out—December						Grand
	2	3	4	5	6	8	Total
No. of days after start of experiment	1	2	3	4	5	7	
No. of stations represented	64	64	76	76	76	71	427
Total number of torpedoes represented	128	128	152	152	152	142	854
No. of torpedoes taken	17	49	58	36	42	35	237
Per cent taken	13.3	38.3	38.2	23.7	27.6	24.6	**27.8**

COCOANUT OIL

	Dates Put Out—December						Grand
	2	3	4	5	6	8	Total
No. of days after start of experiment	1	2	3	4	5	7	
No. of stations represented	64	64	76	76	76	71	427
Total number of torpedoes represented	128	128	152	152	152	142	854
No. of torpedoes taken	20	35	36	25	18	16	150
Per cent taken	15.6	27.3	23.7	16.4	11.8	11.3	**17.6**

PARAFFINE OIL—CHECK

	Dates Put Out—December						Grand
	2	3	4	5	6	8	Total
No. of days after start of experiment	1	2	3	4	5	7	
No. of stations represented	64	64	76	76	76	71	427
Total number of torpedoes represented	128	128	152	152	152	142	854
No. of torpedoes taken	5	17	23	12	15	12	84
Per cent taken	3.9	13.3	15.1	7.9	9.8	8.5	**9.8**

Corn oil leads, with 42.6 per cent taken, followed by sunflower oil, with 27.8 per cent; cocoanut oil, with 17.6 per cent, and paraffine oil, with only 9.8 per cent.

The percentages in this test range somewhat lower than the former experiment, 1-A, due to the large number of torpedoes put out in a comparatively small area.

Fig. 2 presents in graphic form the successive daily preference of rats for the different kinds of torpedoes.

It is interesting to note that on the fourth day there was a decided drop in the consumption of the torpedoes. There was .31 inch of rain at that time. This would suggest that corn-oil-treated torpedoes be used in dry weather, otherwise their efficiency is greatly reduced and considerable material might be wasted.

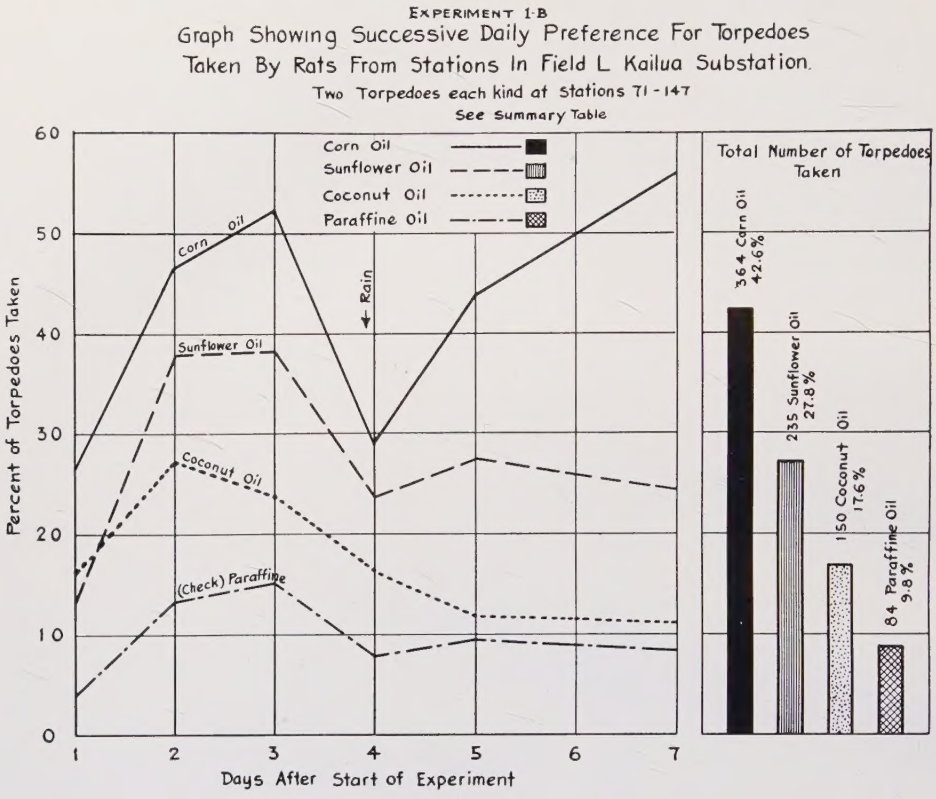


FIG. 2.

Experiment 1-C:

Another small test was conducted using only one torpedo of each kind in each station.

A total of 90 torpedoes of each kind were put out five different days.

The number taken of each kind follows:

	Number Taken	Per Cent
Corn oil	49	54.4
Sunflower oil	21	23.3
Cocoanut oil	20	22.2
Paraffine dipped	9	10.0

Corn oil continued to lead by a good margin, 54.4 per cent being taken as compared with the other treatments (sunflower oil, 23.3 per cent; cocoanut oil, 22.2 per cent, and paraffine 10.0 per cent). The total taken in all amounted to less than in the former experiments, probably due to a smaller rat population.

With only one torpedo of each kind available in each station, there was no tendency to open torpedoes and waste wheat, which was noted in the former experiments.

Dry Thallium Wheat in Dipped Wrapper Versus Corn Oil Wheat in Undipped Wrapper

Experiment 2-A:

A small test was conducted to determine the difference, if any, between torpedoes of dry thallium wheat dipped in corn oil, and torpedoes filled with corn-oil-saturated wheat, but not dipped. These treatments were checked with paraffine-dipped torpedoes.

This test was too small to draw conclusions, but it did show the trend. Out of a total of 120 torpedoes of each kind put out, 30 per cent of the dry wheat torpedoes dipped in corn oil were taken; 18.3 per cent of the torpedoes of corn oil in wheat with plain non-oil wrapper were taken, while only 13.3 per cent of the paraffine-dipped torpedoes were taken.

The detailed results follow:

No. of Torpedoes Put Out	No. of Torpedoes (Dry Wheat) Dipped in Corn Oil	Corn Oil in Wheat With Plain Non-oil Dipped Wrapper	Paraffine Dipped Plain Torpedoes
December 28..... 72	19	11	9*
December 29..... 48	17	11	7†
Total 120	36	22	16
Per cent taken.....	30	18.3	13.3

This table shows that it is of first importance that the paper wrapper be saturated with corn oil whether the wheat inside is saturated or not. If the wheat only is saturated and the torpedoes are not dipped, then sufficient oil must be put into the wheat to thoroughly soak the paper wrapper to make it really attractive. Subsequent experimentation indicated that this was not economical, as is discussed later in this paper. The wrappers of the torpedoes containing corn oil in the wheat naturally became somewhat oily from the oil in the wheat, but not saturated to any extent, as compared with those actually dipped in corn oil and allowed to drain on a screen.

Dry Thallium Wheat Versus Corn Oil Wheat Torpedoes When Both Have a Corn Oil-Dipped Wrapper

Experiment 2-B:

Another small test was put out to test the difference between dry thallium wheat and corn oil wheat when both kinds had been dipped in corn oil.

* All taken from three stations only.

† Same as above, only three different stations were attacked and torpedoes removed including the paraffine ones.

The results are tabulated below:

BOTH KINDS OF TORPEDOES DIPPED IN CORN OIL

	Dry Wheat Inside					Corn Oil Wheat Inside				
March	11	12	13	14	Total	March 11	12	13	14	Total
Torpedoes put out	154	154	77	77	462	154	154	77	77	462
Torpedoes taken	54	57	42	46	199	58	54	47	47	206
Per cent taken	35.1	37.0	54.5	59.7	**43.1**	37.7	35.1	61.0	61.0	**44.6**

These results show that there was no preference between the dry wheat torpedo and the saturated wheat torpedo, provided they were both dipped in corn oil after making. This emphasizes the necessity of having the wrapper soaked with corn oil.

Corn Oil Versus Paraffine Torpedoes Placed Together at Manoa Substation

The study of the use of corn oil versus paraffine-dipped torpedoes was continued at Manoa substation under extremely wet conditions. It was found that with fewer torpedoes put out (one of each kind in one place) the tendency to open torpedoes and waste the wheat was entirely absent.

It was also noted with less bait available the percentage ratio of paraffine to corn oil increased. In the stations receiving two each, corn oil was 50 per cent taken, while paraffine was 14 per cent taken. Stations receiving only one of each kind gave a figure of 82 per cent for corn oil and 48 per cent for paraffine. Ants or slugs were found on some of the corn oil torpedoes remaining untouched on the second day. In some cases small holes were eaten in the paper. However, the number of torpedoes taken after three days would indicate that the rats did not pay much attention to either the ants or the slugs.

The tests discussed up to this point tend to show that rats, having found the torpedo stations, choose the various kinds of torpedoes in the amounts noted. In case there was not enough torpedoes to supply the demand, all would be taken and no preference could be determined. The ability of the rats to locate one or the other of the baits could not be detected by this group or station method.

It now remained to test the rat's ability to find isolated torpedoes of paraffine compared to corn oil when each are placed separately in or along the edge of big cane. This was tested out in Experiment 4, both at Kailua and Manoa substations.

Corn Oil Versus Paraffine Torpedoes When Spaced Singly

Experiment 4:

Single torpedoes of corn oil and paraffine were placed 10 to 15 feet apart, alternating, along the edge of big cane. The results obtained from this study at Kailua are tabulated below:

	Corn Oil	Paraffine
No. of torpedoes put out	470	470
No. of torpedoes taken	344	125
Per cent taken	**73.2**	**26.6**

This test is believed to be the best index of the usefulness of corn oil to increase the attractiveness of the thallium wheat.

The final percentages of this test are more favorable to corn oil than the previous tests, showing 73.2 per cent of the corn-oil-dipped torpedoes taken compared with 26.6 per cent of the paraffine torpedoes taken.

Corn Oil and Paraffine Mixture Versus Pure Paraffine When Torpedoes Are Spaced Singly

Having determined that corn oil was attractive to rats, it was desirable to attain greater waterproofing characteristics in the corn oil torpedo.

Mixtures of paraffine and corn oil were made up by adding varying amounts of corn oil to melted paraffine. Into these mixtures the fibre spun torpedoes were dipped by means of a wire basket in the same way as is done with pure paraffine.

Mixtures of corn oil and paraffine were softer and less waterproof than pure paraffine, depending on the amount of corn oil added. However, amounts up to 175 cc. of corn oil per pound of paraffine did not seriously injure it as a waterproofing material.

Experiment 5:

A test was put out at the Manoa substation, using torpedoes which had been dipped in a corn oil-paraffine mixture containing 175 cc. of corn oil per pound of paraffine. This was tested against pure paraffine-dipped torpedoes, both kinds being spaced 10 to 15 feet apart alternating with each other as was done in the previous experiment (No. 4).

The results of this test are summarized as follows:

SUMMARY OF TORPEDOES TAKEN BY RATS: CORN OIL AND PARAFFINE MIXTURE VS. PURE PARAFFINE

Corn Oil and Paraffine Mixture

	Jan. 27 1st Day	Jan. 28 2nd Day	Jan. 29 3rd Day	Totals
No. of torpedoes out	171	171	171*	513
No. of torpedoes taken	67	51	30	148
Per cent of torpedoes taken	41.6	29.8	17.5	**28.9**

Pure Paraffine

	Jan. 27 1st Day	Jan. 28 2nd Day	Jan. 29 3rd Day	Totals
No. of torpedoes out	171	171	171*	513
No. of torpedoes taken	23	22	16	61
Per cent of torpedoes taken	13.4	12.8	9.4	**11.9**

These data are presented graphically in Fig. 3.

It should be noted here that the rat population appeared to be comparatively

* Rainfall on the previous night.

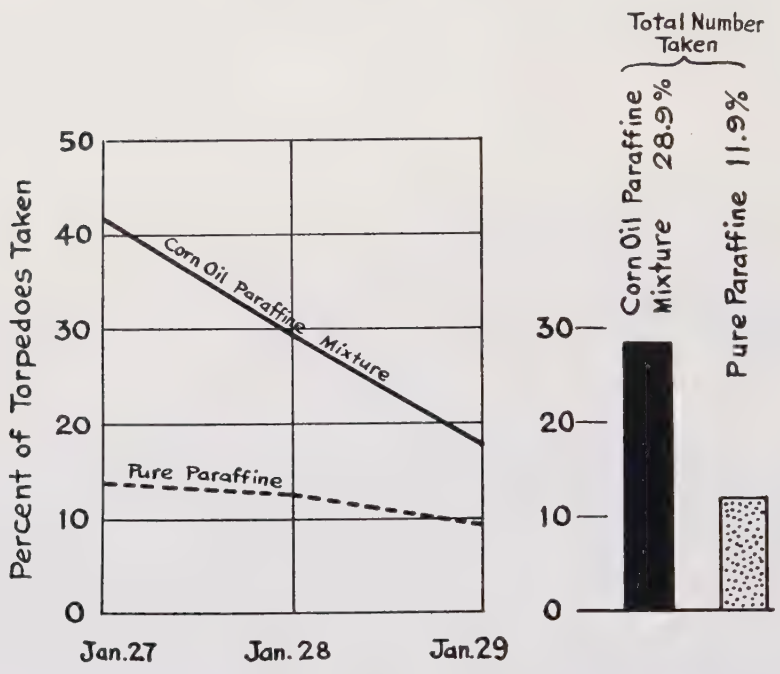


FIG. 3.

small, hence there were rather large areas in which no torpedoes of either kind were disturbed.

The only places where rats appeared numerous were along the edges of the field next to brush land. So the percentage of torpedoes taken was fairly low, but the ratio between the two kinds continues to favor the corn-oil-treated torpedoes.

Amounts of Material

The amounts of paraffine used will vary somewhat according to the temperature of the melted paraffine and the length of time the torpedoes are held in the hot wax.

In the trial dipping, 50 pounds of wheat torpedoes were treated with 5.2 pounds of corn oil-paraffine mixture, which gave the torpedoes a moderately heavy coating. This mixture was made up in the proportion of 175 cc. of corn oil to one pound of paraffine.

As this corn oil had a specific gravity of .91, 175 cc. are equivalent to 159.25 gms. This is 25.9 per cent by weight of the resultant mixture of corn oil and paraffine, which amounts to very slightly more than an even one part of corn oil

to three parts of wax. For practical purposes it will not be necessary to measure more accurately than this.

Modifications may be made as circumstances dictate, such as spraying the torpedoes, with or without dipping in paraffine, though these points were not studied in this endeavor.

Summary

The results of the tests performed to make thallium wheat torpedoes more attractive may be summarized as follows:

Rats showed a decided preference for corn oil over sunflower oil, cocoanut oil or paraffine as a material to saturate the paper torpedoes.

There was no waste of the wheat if only one or two torpedoes were put out in a place.

It was found that dry thallium wheat made into a torpedo and dipped was much better than a small amount of corn oil put into the wheat in an undipped wrapper. As long as the torpedo was dipped in corn oil, it made no difference whether the wheat contained corn oil or not.

The best test of the attractiveness of corn oil over paraffine was carried out by placing the two kinds of torpedoes singly and alternating, spaced 5 to 15 feet apart in or along a cane field. Seventy-three per cent of the corn oil torpedoes were taken, while only 26.6 per cent of the paraffine torpedoes disappeared in the same period.

A mixture of corn oil and paraffine (one part of corn oil to three parts of paraffine by weight) was applied successfully to a trial lot of torpedoes. This treatment offers the best practical method of combining corn oil with paraffine for waterproofing thallium wheat torpedoes.

Further Studies on the Distribution of Soil Moisture Under the Border Method of Irrigation

By H. R. Shaw

A recent issue of *The Hawaiian Planters' Record** reported a series of studies on the penetration and distribution of soil moisture on three distinct plantation soil types and under three methods of irrigation. The investigation indicated that under the Hawaiian contour method at the Waipio substation and under the long line method of irrigation at Waimanalo, the lateral penetration of moisture to each side of the furrow seldom exceeded 24 inches regardless of the quantity of irrigation water applied. The vertical penetration was roughly proportional to the quantity of water applied at the surface. Soil moisture analyses, based on the "relative wetness" or ratio between total moisture content and the moisture equivalent, demonstrated that at all points within the zone of wetted soil caused by the irrigation, the soil was at the same relative moisture content. The soil immediately outside the visible wetted zone was at a relatively low moisture content, and it was apparent that such soil had received no moisture from the current irrigation. Moreover, the investigation demonstrated that there is no appreciable movement of soil moisture after 48 hours from the time of irrigation, and that the effectiveness of capillary attraction in the movement of water from moist to dry soil is negligible. The evidence gained from the investigation led to the conclusion that each increment of soil must be wetted to its maximum field capacity, the greatest amount of water that can be held by the soil against the force of gravity, before other increments of soil can be wetted.

Similar studies were reported in the previous paper on the distribution of moisture under the border method of irrigation in a field at the Ewa Plantation Company. It was impossible at that time to conduct the investigation in a plowed field immediately after the first irrigation as had been the case with the studies on contour and on long line irrigation. The studies were made in a field of cane 5 to 6 feet high which had received 15 irrigations prior to the period of the investigation. It was found that the entire soil mass vertically below the bed of the border was at its maximum field capacity to an indefinite depth exceeding 10 feet. Consequently it was impossible to determine the exact extent of moisture penetration caused by the current irrigation. It was concluded that "quantities of water applied in early irrigations and not used by the feeding roots of the plant pass to the lower soil horizon until each successive increment of soil is filled to its maximum field capacity. As more of such excessive applications of water are made, the water probably percolates through the soil until it reaches the subterranean water table. In view of the preceding evidence on the failure of capillary attraction to convey water for any distance through the soil, it appears improbable

* "The Distribution of Soil Moisture After Irrigation," Shaw, H. R., *Hawaiian Planters' Record*, Vol. XXXVI, January, 1932.

that any water penetrating below the normal root range is ever recovered by the plant."

An opportunity arose in January, 1932, to study at the Ewa Plantation the manner and extent of soil moisture distribution under the border method of irrigation in a field previously occupied by a labor camp and gardens, and which was being plowed and put under cultivation to sugar cane for the first time. The soil was a finely divided, grayish brown loam free from rocks and apparently from soil irregularities. The greater portion of the field was on a gentle and uniform natural gradient of approximately 1.5 per cent. The borders were 20 feet wide from levee to levee, and were 1050 feet in length. Small furrows, 4 to 6 inches deep, were made in parallel 5 feet apart in the border in order that certain economies in water application and in the subsequent control of weed growth might be effected. After the cane has reached an age of 4 to 5 months, it is planned to fill and level these small furrows, subsequent irrigations being made by the more usual method of flooding the entire border. This adaptation, which has been used successfully on the plantation of the Hawaiian Commercial and Sugar Company in 1931, is termed the long line-border combination method, as the distribution of water at the start of the crop is typical of the long line or furrow method.

Seven adjoining borders in the center of the field were chosen for the investigation. Four borders were given a normal first irrigation by plantation labor. Although it was not possible to measure the quantity of water applied to each border, the average application was estimated to be approximately 2.0 acre inches per acre. At points in each border 625, 725 and 900 feet from the level ditch, the border bed was levelled from side to side for a distance of 10 to 15 feet so that the application of water was typical of the true border method of irrigation. The three alternate borders remained unirrigated so that the lateral penetration of moisture might be determined.

On the day following the irrigation, a narrow trench was dug athwart each irrigated border at points 625, 725 and 900 feet from the level ditch. The line of demarcation between moist soil caused by the current irrigation and the relatively dry soil was clearly visible on the face of the trench. The perimeter of this wetted zone was marked by pins set in the trench face at intervals of about three inches. The coordinates of each pin were recorded, and the zone mapped.

Soil moisture samples were taken at various spots within and without the wetted area. In each position two samples of approximately 150 grams each were taken. One sample was weighed within 12 hours of the time of sampling, dried at 110° C. in an electric oven for 48 hours, and the total moisture content on an oven dry basis determined. The other sample was divided into two portions and the moisture equivalent of the soil determined in duplicate. The moisture equivalent of Hawaiian soils has been found to bear a remarkably constant relationship to the maximum field capacity of the same soil. This relationship may be expressed as: maximum field capacity = moisture equivalent $\times$ 1.1.

The basis used in the comparison of soil moisture data in the studies described here is the "relative wetness" or total moisture content $\times$ 100 $\div$ moisture equivalent. If the "relative wetness" of a set of samples ranges in value from 100 to 110, the soil may be considered to be at its maximum field capacity. If the value

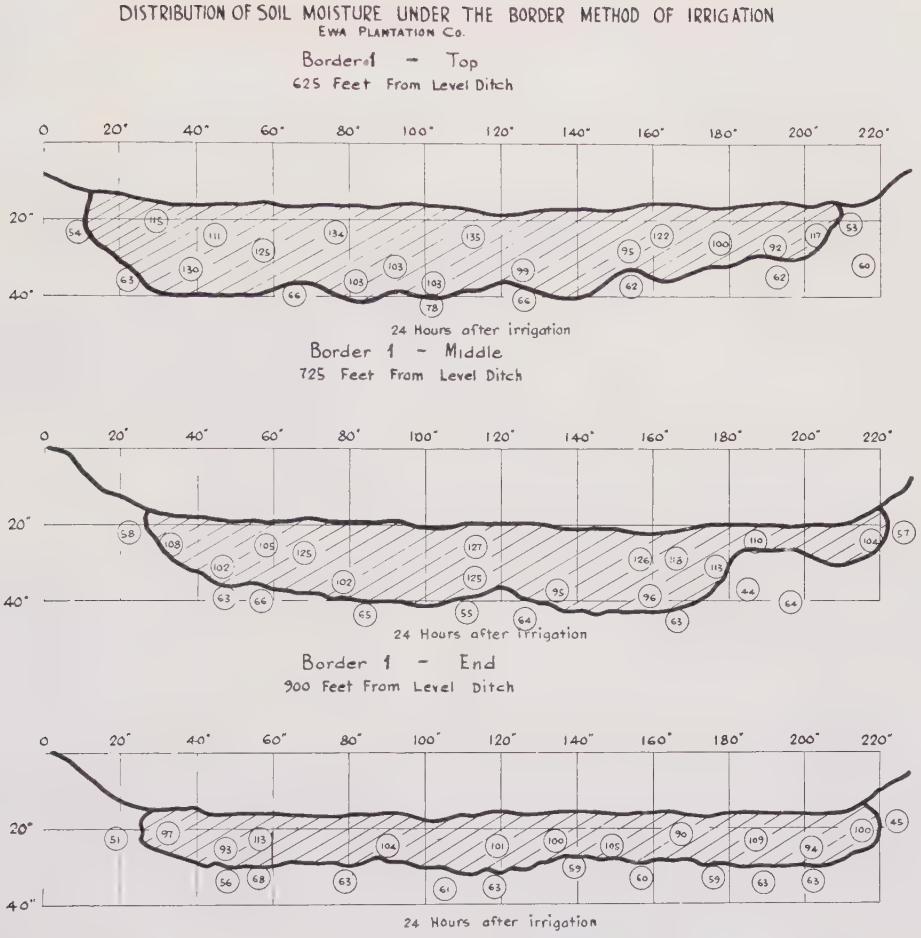

DISTRIBUTION OF SOIL MOISTURE UNDER THE BORDER METHOD OF IRRIGATION
EWA PLANTATION CO.
Border 1 - Top
625 Feet From Level Ditch
24 Hours after irrigation
Border 1 - Middle
725 Feet From Level Ditch
24 Hours after irrigation
Border 1 - End
900 Feet From Level Ditch
24 Hours after irrigation

FIG. 1.

Distribution of soil moisture under the Border Method of irrigation. Figures in circles refer to the "Relative Wetness" of the soil, or Total Per Cent Moisture x 100 divided by the Moisture Equivalent.

is considerably above 110, it is assumed that the soil and water are not yet in equilibrium and that further movement due to gravity may take place. If the value is considerably lower than 100, it appears safe to assume that the soil is far below its maximum field capacity, and probably that no moisture has been added to the soil by the current irrigation.

Fig. 1 shows the distribution of soil moisture 24 hours after the first irrigation by the border method to land of uniform and gradual slope. At a point 625 feet from the level ditch the vertical penetration of moisture averages 20 inches below the border bed. The lateral penetration is negligible and extends but a few inches beyond the extremes of the surface application of water. At 725 feet from the level ditch the vertical penetration does not exceed 20 inches and is considerably less at each side of the border where the surface application was apparently less than at the center. At 900 feet from the level ditch or 150 feet from the end of the border, the vertical penetration is not over 12 to 14 inches or about half the

penetration at the other points in the border. Inspection of the soil moisture data, as expressed by the "relative wetness" ratio, reveals that at points 625 and 725 feet from the level ditch, the soil near the surface is at a moisture content somewhat greater than its maximum field capacity and that a slightly greater penetration due to gravity may be expected after 24 hours. There is no evidence, however, of a gradation in moisture distribution at the lower limits of the wetted zone. The "relative wetness" of samples taken just within the visible perimeter of the wetted area indicates that the soil is at its maximum field capacity while the ratio of samples taken but a few inches outside the wetted area ranges from 50 to 65 per cent of the soil's possible capacity, indicating a sharp transition between moist and dry soil. The soil at all points within the wetted zone 900 feet from the level ditch is at its maximum field capacity while the soil immediately outside the perimeter is at a relatively low moisture content.

Fig. 2 demonstrates the effect of slight changes in the slope of the surface of the border on the resulting penetration of moisture. At 625 feet from the level ditch the shape and extent of the wetted area resemble Fig. 1 at the same point.

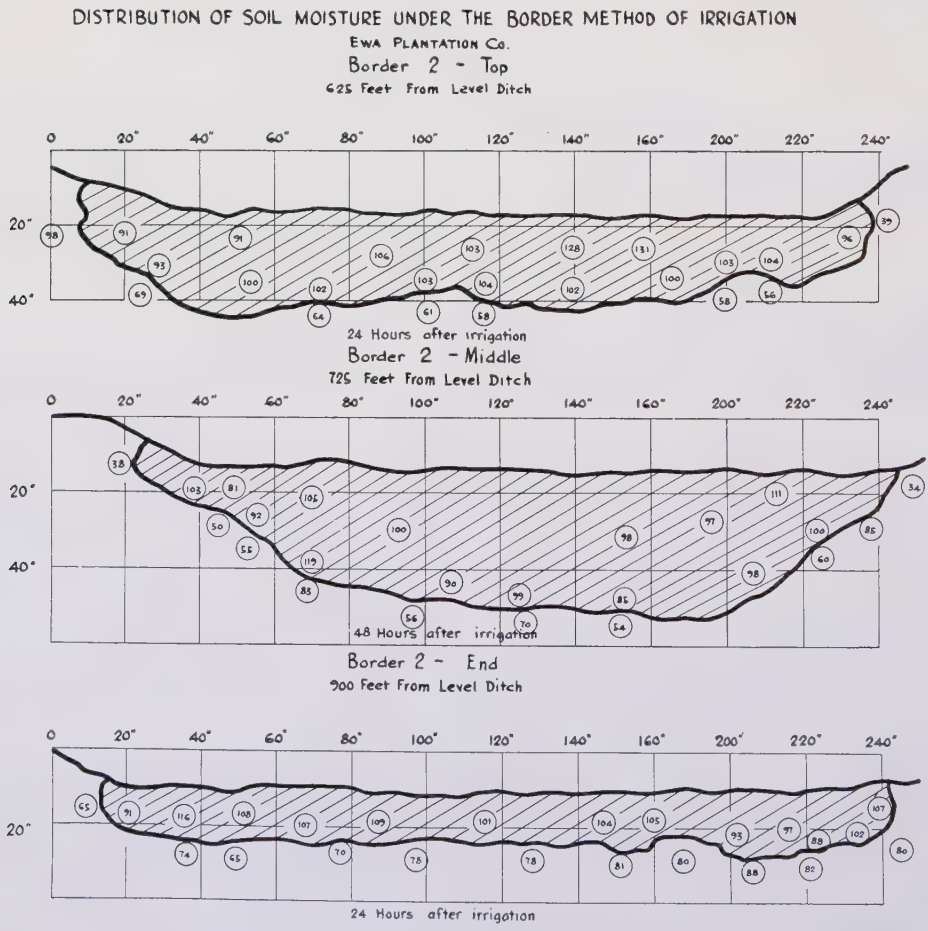

DISTRIBUTION OF SOIL MOISTURE UNDER THE BORDER METHOD OF IRRIGATION
EWA PLANTATION CO.
Border 2 - Top
625 Feet From Level Ditch
24 Hours after irrigation
Border 2 - Middle
725 Feet From Level Ditch
48 Hours after irrigation
Border 2 - End
900 Feet From Level Ditch
24 Hours after irrigation

FIG. 2.
Distribution of soil moisture under the Border Method of irrigation.

With two exceptions, the "relative wetness" ratio indicates that the soil is at its maximum field capacity at all points within the wetted zone, and consequently that there will be no further downward movement of moisture. A slight swale or depression in the border 725 feet from the level ditch resulted in an accumulation of water on the surface and a relatively deep vertical penetration. The penetration at the center of the border ranges from 36 to 40 inches, with an abrupt upward gradation at the sides of the border. The penetration of moisture 900 feet from the level ditch again is comparatively slight and seldom exceeds 14 inches. The relative moisture content of the dry soil immediately below the wetted zone is somewhat higher than that in other cases, due, probably, to local surface conditions occurring before the field was plowed which prevented the exhaustion of residual soil moisture to as great an extent as that in other parts of the field. Such a condition might be caused by a road, barren area, or group of buildings which would allow a penetration of moisture from rainfall but would prevent an exhaustion of soil moisture by plant growth.

The penetration of moisture in Border 3 at a point 625 feet from the level ditch resembles that of other cases shown except that there appears to be a slightly greater lateral penetration of moisture at the left-hand edge of the border caused apparently by a slight depression and consequent accumulation of surface water at that point. The vertical penetration of moisture 900 feet from the level ditch is even less than in other cases noted, the penetration averaging less than 8 inches.

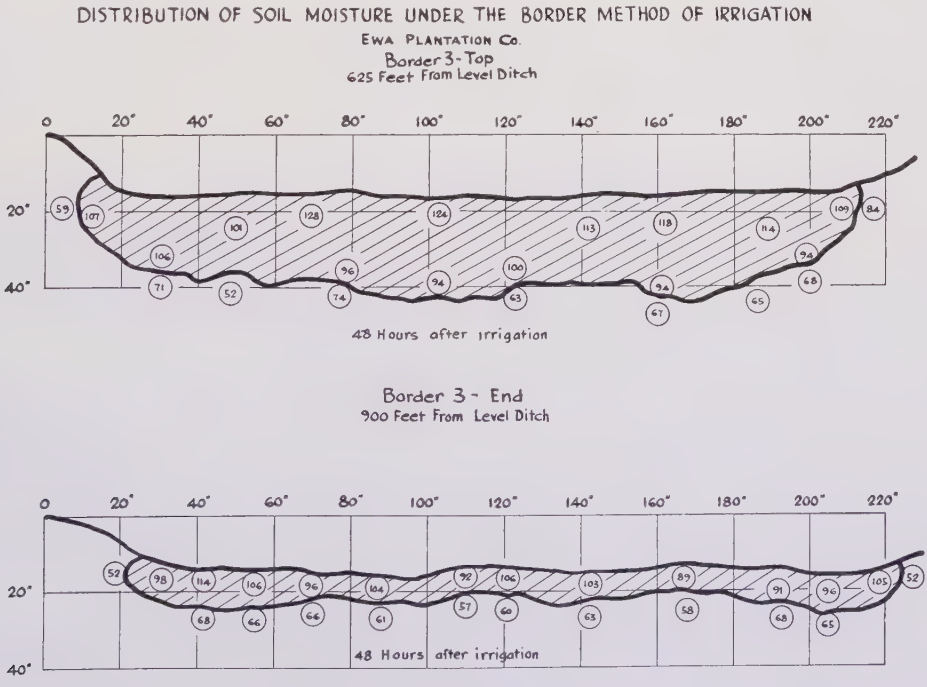

DISTRIBUTION OF SOIL MOISTURE UNDER THE BORDER METHOD OF IRRIGATION
EWA PLANTATION CO.
Border 3 - Top
625 Feet From Level Ditch
0 20" 40" 60" 80" 100" 120" 140" 160" 180" 200" 220"
20"
40"
48 Hours after irrigation
Border 3 - End
900 Feet From Level Ditch
48 Hours after irrigation

FIG. 3.

Distribution of soil moisture under the Border Method of irrigation. Figures in circles refer to the "Relative Wetness" of the soil, or Total Per Cent Moisture x 100 divided by the Moisture Equivalent.

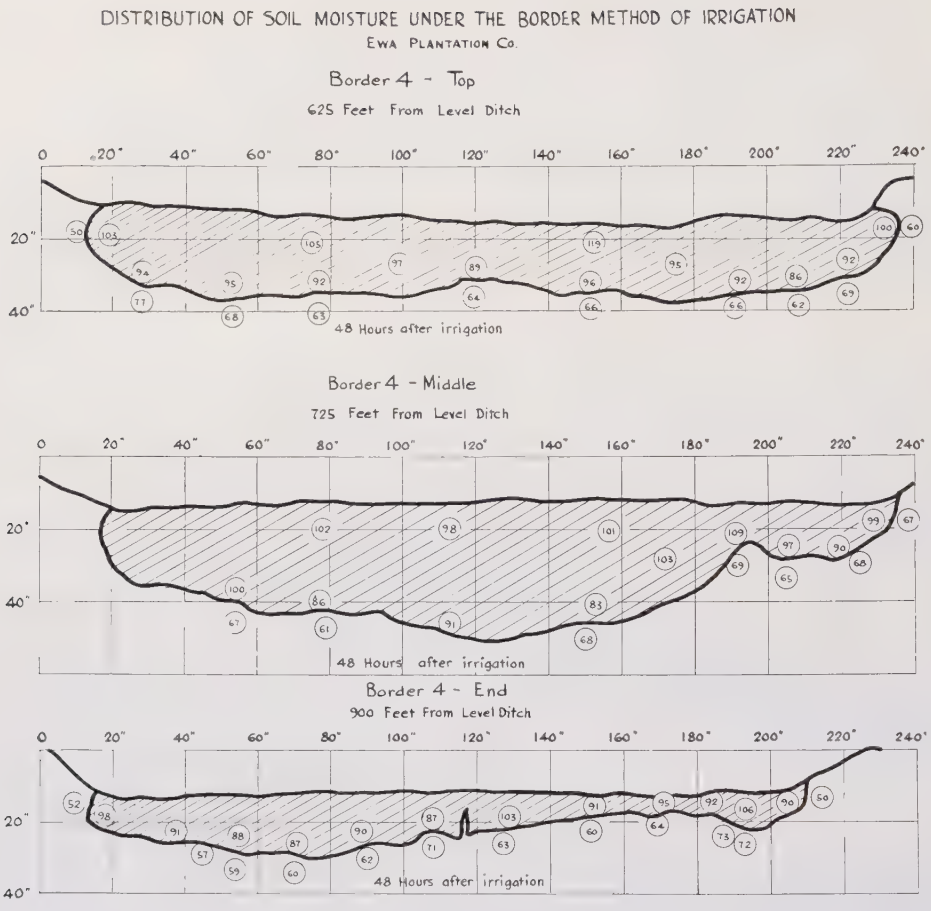

DISTRIBUTION OF SOIL MOISTURE UNDER THE BORDER METHOD OF IRRIGATION
EWA PLANTATION CO.
Border 4 - Top
625 Feet From Level Ditch
0 20" 40" 60" 80" 100" 120" 140" 160" 180" 200" 220" 240"
20"
40"
48 Hours after irrigation
Border 4 - Middle
725 Feet From Level Ditch
48 Hours after irrigation
Border 4 - End
900 Feet From Level Ditch
48 Hours after irrigation

FIG. 4.

Distribution of soil moisture under the Border Method of irrigation. Figures in circles refer to the "Relative Wetness" of the soil, or Total Per Cent Moisture x 100 divided by the Moisture Equivalent.

The trench constructed 725 feet from the level ditch in this border was abandoned because of a localized condition resulting in an accumulation of residual soil moisture which made it difficult to locate the limits of the wetted area.

Fig. 4 is another example of the effect of a changed surface gradient on the resulting penetration of moisture. The penetration at 625 feet from the level ditch averages 21 inches, but that at 725 feet from the ditch is considerably greater, ranging from 36 to 40 inches in the center and averaging 26 inches. The greater penetration in the second case is probably due to a change in surface gradient causing a check or slight accumulation of irrigation water at this point. The penetration of moisture 900 feet from the level ditch is again relatively scant except at the left half of the border where a change in level from side to side apparently resulted in a slight accumulation of surface water.

In order to gain an idea of the nature of soil moisture distribution under the long line-border combination method by which irrigation water to the seed and young cane is applied in small, shallow furrows 5 feet apart rather than by flood-

ing the entire border, trenches were dug athwart the border at points 250 and 475 feet from the level ditch in Border 1. The wetted zones, which were clearly visible on the trench face, were marked and plotted in the manner described previously although no soil moisture samples were taken. It may be seen from Fig. 5 that the distribution of moisture by this method is typical of that under the long line method of irrigation described in a previous report. The wetted zones are roughly elliptical in shape with the major axis in a horizontal direction. The vertical penetration 250 feet from the level ditch was slightly over 20 inches below the base of the furrow. The lateral penetration was slight, and there was no

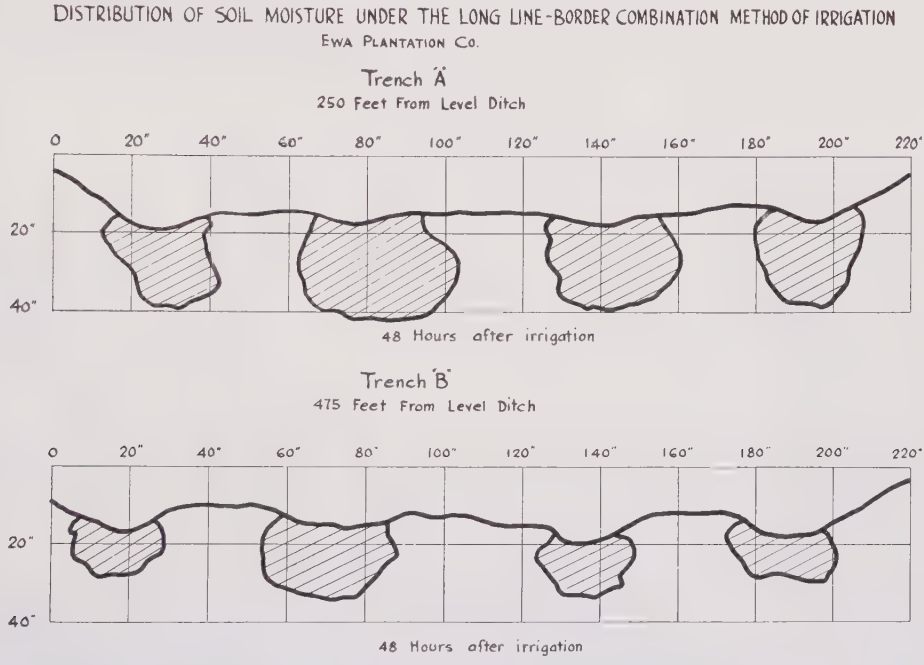


FIG. 5.
Distribution of soil moisture under the Long Line-Border Combination Method of irrigation.

apparent movement of moisture into the ridges between furrows. At 475 feet from the level ditch the vertical penetration was about 12 inches and the lateral penetration was reduced from 4 to 6 inches of that in corresponding furrows at 250 feet. In other words, a variation in the amount of surface application affected greatly the resulting vertical penetration, but affected only slightly the resulting lateral penetration.

In Table I is given the true area of the wetted zone, and the average vertical penetration of moisture in each of the cases studied. The area of the wetted zone was determined by tracing the mapped outline of each wetted zone with a planimeter and making the proper scale conversion. The "effective border width" is the width in inches of that portion of the border to which irrigation water was actually applied rather than the width from levee to levee. The average depth of

penetration, was determined by dividing the area in square inches by the effective border width.

TABLE I

AREAS OF WETTED ZONES RESULTING FROM FIRST IRRIGATION APPLICATION

Border	Area of Wetted Zone Sq. Ins.	Sq. Ft.	Effective Width of Border	Average Depth of Moisture Penetration
1—Top	3903.768	27.102	196 inches	20 inches
1—Middle	3213.708	22.317	192 "	17 "
1—End	2563.080	17.799	192 "	13 "
2—Top	4626.688	32.130	206 "	22 "
2—Middle	5369.324	37.287	200 "	27 "
2—End	2983.688	20.720	208 "	14 "
3—Top	4455.816	30.943	200 "	22 "
3—End	1570.708	10.908	198 "	8 "
4—Top	4436.100	30.806	212 "	21 "
4—Middle	5586.200	38.793	214 "	26 "
4—End	2195.048	15.243	194 "	11 "

The data in Table I demonstrate that within the relatively short distance of 275 feet there may be a considerable difference in the area of soil wetted by an irrigation application, and in the vertical distance penetrated by the water. In the cases reported here, the average depth of penetration at a point 900 feet from the level ditch is about one-half of that 275 feet nearer the ditch. The area wetted by the irrigation water 900 feet from the level ditch is from one-third to two-thirds of that nearer the ditch. The probable causes and results of this variation will be discussed in greater detail later in the paper.

That a considerable fluctuation in the quantity of irrigation water applied at various points in the border if the land surface is not level from side to side and uniform in slope, is evident from the variations noted in the size of the wetted areas resulting from the irrigation. An approximation of the quantity of water applied to the surface of a homogeneous soil when certain other factors are known may be gained from the equation:

$$D = P \times V \times d$$

Where D = the depth of the surface application in acres inches per acre; P = the range in soil moisture under consideration; V = the volume weight or apparent specific gravity of the soil; and d = the depth of moisture penetration in inches.

Three of the factors in this equation may be estimated closely for the soil under consideration. 'P', the range in soil moisture percentage involved, may be determined by subtracting the average per cent moisture of the dry soil outside the wetted zone from the average per cent moisture of the soil within the wetted zone. 'V', or the volume weight of the soil, has been determined by the writer for a large number of Hawaiian soils,* some of which were in the close vicinity of the field under consideration. An estimated value of 1.1 for the volume weight of

* "Variation in the Volume Weight of Hawaiian Soils," H. R. Shaw, Progress Report, Project A-4, Expt. Sta. H. S. P. A.

the soil may be considered sufficiently accurate. The value of 'd', or the average depth of moisture penetration is given in the last column of Table I.

With three of the factors of the equation known, an approximation of the quantity of irrigation water applied at various points in the border is given in Table II.

TABLE II

VARIATION IN THE QUANTITY OF IRRIGATION WATER APPLIED AT VARIOUS POINTS IN A BORDER, AS OBTAINED FROM THE EQUATION: $D = P \times V \times d$

Border	Soil Moisture Percentage		'P' or Range in Soil Moisture	'V' Estimated Volume Weight	'd' Depth of Moisture Penetration	'D' Probable Surface Application of Irrigation Water
	Before Irrigation	After Irrigation				
1—Top	16.7	29.3	.126	1.1	20 inches	2.77 acre inches
1—Middle	16.5	29.2	.127	1.1	17 "	2.37 per acre
1—End	16.2	29.1	.129	1.1	13 "	1.84 "
2—Top	15.5	28.2	.127	1.1	22 "	3.07 "
2—Middle	15.4	26.7	.113	1.1	27 "	3.36 "
2—End	21.1	29.6	.085	1.1	14 "	1.31 "
3—Top	16.3	27.2	.109	1.1	22 "	2.64 "
3—End	16.2	26.2	.100	1.1	8 "	0.88 "
4—Top	16.5	25.9	.094	1.1	21 "	2.17 "
4—Middle	18.3	26.1	.078	1.1	26 "	2.23 "
4—End	16.1	24.8	.087	1.1	11 "	1.05 "

Discussion

In general, the evidence of this investigation on the distribution of soil moisture under the border method of irrigation indicates that the penetration of soil moisture is more than adequate for the germination of seed and the growth of the cane plant. It would appear that, with the possible exception of a relatively short distance near the end of the border, the zone of soil moisture penetration is far greater than is necessary for the actual supply of water to the plant. As successive applications of irrigation water in excess of the needs of the plant are made, it seems probable that the lower limit of the moist zone will move downward by gravity until the entire soil mass for an indefinite distance below the bed of the border will be at its maximum field capacity. It appears, therefore, that precautions must be taken with the border method of irrigation, even more than with other methods, to prevent the drainage of irrigation water and soluble nutrients below the potential root zone of the plant.

The use of the long line-border combination method seems to be effective in reducing excessive losses of irrigation water during the early portion of the crop periods. The wetted zone below each furrow, as shown in Fig. 5, is adequate for the germination of seed and the early growth of the cane. The fact that there appears to be no lateral movement of moisture into the ridges between furrows should also prove effective in the curtailment of weed growth between cane rows, previously a serious objection in many quarters to the border method of irrigation. However, in soils of the type described here and in regions with little rain-

fall, it would appear desirable if not imperative to level the furrows and revert to the usual border method as soon as the cane develops considerable foliage and an extensive root system. It seems certain that in localities dependent for long periods solely on irrigation, root development in the dry ridges between furrows will be handicapped, if not completely curtailed. The complete distribution of water across the entire border would surely tend toward a greater lateral root development and possibly a greater availability of soluble nutrients in the soil.

The necessity for careful preparation and leveling if a uniform distribution of moisture is to be gained seems apparent from the results of the investigation. A change in level from side to side may affect seriously the depth of penetration of soil moisture. Changes in gradient down the length of the border may also be reflected in excessive penetration of moisture in depressions and an inadequate zone of moist soil on the high spots.

The reasons for the relatively scant penetration of moisture near the end of each border deserve more than passing comment. The previous report on the distribution of soil moisture under the border method after the fifteenth irrigation mentioned this effect as follows: "With the technique now used in border irrigation, the water is turned off at the headgate when the advancing sheet of water is yet some distance from the end of the border. It seems not unlikely that there may be a short distance, between the position of the advancing water at the time the supply is stopped and the point at which water backs up from the end of the border, at which the penetration of moisture might be inadequate, and a modification of the colloidal properties of the soil such as to cause a hardpan formation might occur. Such a zone of inadequate penetration near the end of the border is often reflected in reduced cane growth under the border method of irrigation."

The assumption made in the preceding paragraphs seems to be verified by the results of the present investigation. The inadequacy of moisture penetration 150 feet from the end of the border in each case is certainly due to a limitation of supply rather than to an increased gradient or to the physical nature of the soil. The limited area of moist soil at this point seems likely to jeopardize the opportunity for optimum plant growth. Experience with the border method of irrigation indicates that the inadequate penetration of moisture is caused, not by the length of the border, but by stopping the stream of water at the headgate before the advancing sheet reaches the end of the border. It would appear, however, that the shorter the border the greater the control of the water. Hence it seems probable that with borders from 300 to 500 feet long the stream at the headgate might be controlled with much greater precision than is the case with borders 1000 to 1200 feet long. Another suggestion for the elimination of the zone of inadequate moisture penetration near the end of the border has been the construction of small earth or trash dams which will check the flow of water and allow a greater penetration of moisture. A third possibility is the construction of small drainage ditches from the end of the border to the next lower level ditch. Thus, the stream would not be turned off at the headgate until the advancing sheet of water had completely reached the end of the border. Excess water would then be drained from the end of the border to the level ditch below.

Summary

1. This paper reports a study on the distribution of soil moisture under the border method of irrigation after the first application of water to a newly plowed field on the Ewa Plantation.

2. Trenches were dug athwart each of four borders at points 625, 725 and 900 feet from the level ditch. The zone of wetted soil, visible on the face of the trench, was mapped and studied.

3. The vertical penetration of soil moisture after the first irrigation varied from a minimum of 6 inches to a maximum of 40 inches. The degree of moisture penetration seemed greatly affected by the surface gradient of the land. Lateral penetration was negligible.

4. The area of wetted soil caused by the irrigation application appeared more than adequate for the germination and early growth of cane, and it appeared probable that losses of water and soluble nutrients might occur, especially during the first few months of the crop.

5. The long line-border combination method, by which irrigation water is applied to the seed and young cane in small furrows rather than by flooding, appears to be effective in the conservation of water and the curtailment of weed growth between cane rows. The advisability of reverting to the true border method of irrigation as soon as root and foliage development of the plant has progressed, especially in localities having fine-grained soil and low rainfall, is suggested.

6. The reasons and possible corrective measures for a relatively inadequate penetration of moisture noted near the end of the border are discussed.

7. Soil moisture data indicate that, in general, the soil at all points within the visible wetted zone is at a relatively uniform moisture content. There is a sharp transition between moist and dry soil, the region immediately outside the wetted zone apparently not having received any moisture from the current irrigation. There is no evidence of a movement of soil moisture by capillarity or other means after 48 hours from the time of irrigation, and any movement after 24 hours from irrigation was almost imperceptible.

Acknowledgments

The writer is indebted to George F. Renton, manager, to Harold Dyson, head irrigation overseer, and to J. B. Menardi, Jr., and Burt Bacon, agriculturists, of the Ewa Plantation Company, for the opportunity of conducting this study, and for their hearty cooperation in the prosecution of the work.

Some Observations on Forest Insects at the Nauhi Nursery and Vicinity on Hawaii

By O. H. Swezey

Through the courtesy of the department of forestry, Dr. F. X. Williams and the writer had the opportunity of spending a week the latter part of September and beginning of October, 1931, at the forest nursery on Nauhi Gulch, at an elevation of 5250 feet. This is at the upper edge of the Hilo Forest Reserve, and in the land of Honohina, about 12 miles up from the coast. It is in a region of this great forest belt on windward Hawaii which has never been explored entomologically. During the few days there, we studied the insect faunas of the chief trees making up the jungle in the forest reserve, and the remaining trees in the ranch land which occupies a wide belt above the forest. We also went up the side of Mauna Kea above the forest line to an elevation of 8500 feet.

The koa is a prominent tree of the region, and, as evidenced by standing dead trunks and rotten logs, formerly made up a considerable part of the forest that previously covered the land, which has been occupied by the ranch for a long period of time. There are some remaining live trees on the ranch, particularly in and along gulches. The most prevalent tree in the forest reserve is the lehua. It also extends somewhat up into the ranch area. The mamani makes up a considerable belt of open forest at an elevation of 7000 to 8500 feet, with scattering trees at lower elevations. The naio has scattered stands in the ranch area. Kolea is found sparsely in the forest reserve and also somewhat higher up. The same applies to the olapa. The mamake is not common and Broussaisia is more in evidence in the forest reserve. A species of Coprosma is quite common in the jungle of the forest reserve and is also found in the gulches at higher elevations.

Of the undergrowth making up the jungle of the forest reserve there are many pulu ferns; also thickets of akala, and clumps of a tall species of ohelo are common; puakeawe is also abundant in places.

Certain trees which are usually components of the endemic forests were not observed in the region, namely: Straussia, Bobea, Pelea, Elaeocarpus, Antidesma, Perrotettia, Maba.

Insects Affecting the Koa (*Acacia koa*)

Two species of leafhopper (*Ilburnia koae* and *Ilburnia pseudorubescens*) were found on the new foliage of young trees and on new sprouts on the trunks of old trees. They were the most numerous on young trees, but not numerous enough for significant injury.

An occasional caterpillar of the koa moth (*Scotorythra paludicola*) was found feeding on new foliage, but not numerous enough to be harmful; an occasional larva of the small butterfly, *Lycaena blackburni,* also was found feeding on new foliage.

The growing seeds in pods are badly eaten by larvae of the koa seed moth (*Cryptophlebia illepida* var. *fulva*). Counts were made in 87 pods, and of the possible 644 seeds, only 201 or 31 per cent had matured, while 395 or 61 per cent had been destroyed by larvae of the moth. A few larvae were still feeding on green seeds. From these, four moths matured October 21 to 30.

In dead branches of living trees were found larvae and pupae of one species of native koa borer, *Plagithmysus varians*. A few of the adult beetles were found also in the pupal cells in the wood where they had matured, and had not yet issued. A number of pieces of dead branches containing larvae were taken to the laboratory, and from these 14 beetles matured and issued October 31 to November 16. The living healthy trees were not attacked by this insect, but the larvae were always to be found in the dying branches resulting from crowded growth or lack of nourishment. They were also found in places where trunks of trees had been injured, and in fallen trees. In the latter they were particularly numerous, if the tree had been down a few months. The adult beetles are attracted to fallen trees, broken branches, or dying branches of trees, and place their eggs in cracks or crevices of the bark. On hatching, the larvae feed in the inner fermenting bark, which is their preferred food; on increasing in size they feed also on the outer layer of the wood, forming grooves, where they are feeding beneath the bark. If the bark becomes too dry, they burrow into and feed on the wood exclusively, and when they have reached their full growth, if they have not already burrowed into the wood, they burrow in sufficiently to form a cell for pupation, in which they eventually transform to the adult beetle. The adult beetles issue from round holes which they gnaw through the bark. Sometimes the holes are very numerous in old, dead standing trunks, and this leads to the impression that the trees have been killed by these borers. A study of the habits of the insect demonstrates, however, that it is only a secondary factor, the primary factor being some unfavorable conditions of environment, the insect attack beginning when the tree or its branches are in a dying condition.

Another contributor to the number of holes in standing dead trunks is an oval black beetle (*Oodemas corticis*), the larvae of which feed only in dead and rotten wood. We found many of the beetles as well as the larvae in rotten logs on the ground and in standing dead koa trunks. In the latter were the numerous round holes from which the beetles had issued after becoming mature in their pupal cells. These pupal cells were readily distinguishable from those of the previously discussed borer, being shorter as this beetle is shorter in all stages than the preceding, though the diameter of the hole by which it issues from the tree is about the same. Another distinction is that the borer, *Plagithmysus varians*, issues while the bark is still on; whereas the adults of *Oodemas corticis* only issue at later stages in the decay of the tree.

Rotten koa logs on the ground were found to have quite a miscellaneous population of insects. Among those feeding on the rotten wood besides the Oodemas above, were three species of weevils (*Dryophthorus insignis, D. declivis.* and apparently a new species of Dryophthorus); two kinds of moth caterpillars belonging to the genera Semnoprepia and Thyrocopa, of which none was reared, which would be necessary to determine the species. There were also the wireworm-like

larvae of beetles of the genus Dromaeolus, which probably feed on juices from the wet, rotten wood. No adults were found, and no larvae were reared to maturity, but wing-covers were found belonging to the species *perkinsi*. Real wireworms were also found in the rotten wood where they were probably predators on some of the other insects. These wireworms were larvae of a native species of click-beetles. A few wing-covers and other remains of the beetles were found, which served to identify the species as *Eopenthes konae*. Other predators were: adult carabid beetles of two or three species, mostly a small species which appears to be *Mecyclothorax konanus;* larvae and adults of two staphylinid beetles, *Philonthus scybalarius* and *P. turbidus*. The larva of the latter was found to have an interesting parasite which was a new discovery in the genus Proctotrypes.

Insects of Ohia Lehua (*Metrosideros polymorpha*)

Insects specially feeding on the lehua were not particularly abundant. An occasional caterpillar was found on the foliage which was probably *Scotorythra rara*. None was reared, however. The moths came to light quite numerously. In moss and rotten logs near base of lehua trees a few large pupae were found of the large moth *Scotorythra hyparcha*. It is supposed that the caterpillars of this moth feed on the foliage of lehua, but none was found, however. They must have been fairly common a short time previously, for the moths came to light at night in large numbers.

A leafhopper (*Leialoha lehua hawaiiensis*) was found on the young twigs, but not common. One or more species of leaf-bugs were found. None of these insects was numerous enough to injure the trees. The little psyllids which produce galls on lehua leaves nearly everywhere, were scarce, only occasionally found. A few of a species of Proterhinus bark beetle were beaten from dead twigs. In rotten logs, the same new species of Dryophthorus was found that occurred in koa logs.

Insects of the Mamani (*Sophora chrysophylla*)

A small green mirid bug was very numerous on the foliage of the mamani tree. They did not seem to affect the tree badly, however. Another species of smaller size was also present in some places in less numbers. A few caterpillars were found of some species of Scotorythra, but they failed to mature so that the species was not determined. In dying and dead trees were numerous larvae of the species of borer beetle which is specially attached to mamani: *Plagithmysus blackburni*. Eleven of the adult beetles were collected resting on the branches of one dead tree. These beetles fly up so suddenly when disturbed, that one has to be very quick or he will miss capturing them. The larvae of this beetle work similarly to the species described above on koa trees. The larvae feed in the inner bark of dying trees, or dying branches; then burrow into the wood to form the cell or chamber for pupation and maturing to adult beetles. In the numerous dead or partly dead trees in the region where the mamani predominates, the borer holes are numerous and conspicuous where the bark is off, and this easily leads to the misconception that the trees have been killed by the borers, just as in the case of koa trees. The study of this insect has shown that it is the sickly or dying trees

which are attacked. The mamani tree is adapted to living under very unfavorable conditions such as dry, barren regions, and has continued to exist as a considerable forest at an elevation from about 6500 to 8000 feet in spite of the fact that it has been pastured for a long time. Those trees which succumb from time to time are enough to furnish feeding grounds for this beetle in considerable numbers. A few of the mamani seeds are eaten in the pods by larvae of the moth *Adenoneura plicatum*, which is related to the moth that is so destructive to koa seeds.

Insects of the Naio (*Myoporum sandwicense*)

There were not many of this tree left in the region, but in places were groups of dead trees, and a few that were yet alive. The only insect of importance found associated with this tree was the borer *Plagithmysus perkinsi*, one of the larger species of this group of borers. The larvae were found abundant in dying trees. They were found to be feeding in the healthy bark and wood, and no doubt are partially responsible for the death of the trees.

Insects of Pilo (*Coprosma* sp.)

This medium sized tree was common in the forest reserve and also occurred in the sides of gulches up to about 7000 feet elevation. A small mirid bug was numerous on the foliage, and a few of a species of jassid were collected. None of these was particularly detrimental to the tree. In and beneath the bark of a dead tree at Keanakolu were found several kinds of small beetles: *Proterhinus vulcanus*, *Mirosternus* sp., *Cis porcatus*, *Cis cognatissimus* and *Cis signatus*. None of these has a harmful habit.

Insects of Kolea (*Suttonia lessertiana*)

This tree occurred rather sparsely in general. One small grove was noted at about 6000 feet elevation in the ranch land. The caterpillars of a tortricid moth (*Eulia* sp.) were often found feeding on the leaves of the terminal bud, and also boring in the twigs, thus killing the ends of branches. Sometimes nearly every twig was found injured. There was also an occasional mirid bug on the foliage. A few Proterhinus beetles were beaten from dead twigs.

Insects of Olapa (*Cheirodendron gaudichaudii*)

Only scattered trees of this kind were noted. They were not particularly eaten by insects. Two species of leaf bugs were occasionally collected. The work of the large weevil *Nesotocus munroi* was not noted, but Mr. Ignacio, the forest ranger, later sent us 20 of the beetles which he collected from an olapa tree along the Laupahoehoe trail. The larvae of this beetle live in the decaying bark of dying trees, reaching full growth about the time the bark is entirely decomposed, then they burrow into the wood to form pupal cells, from which the adult beetles issue in due time. They do not injure healthy trees, living only in dying or dead branches or dying trees.

Insects of Mamake (*Pipturus albidus*)

The mamake was rather scarce, but where found was usually considerably attacked by insects, though not particularly injured. The caterpillars of the Kamehameha butterfly (*Vanessa tammeamea*) were found feeding on the foliage but not numerous. A leafminer was numerous in the leaves, the larvae of a small moth. None was reared, but it is probably *Gracilaria neraudicola,* which has been reared from mamake leaves in several localities on the island of Hawaii. A few larvae were found feeding in terminal buds similarly to what larvae of *Epagoge infaustana* do on Oahu, but none matured to demonstrate the identity of the species. A jassid leafhopper, apparently a new species of Nesophrosyne, was found in small numbers.

Insects of Akala (*Rubus hawaiiensis*)

This native raspberry was one of the abundant undershrubs occurring in dense thickets in large areas. Its leaves were considerably eaten by the caterpillars of a small pyralid moth (*Phlyctaenia endopyra*). The stems were conspicuously injured by borers, the larvae of a longicorn beetle (*Plagithmysus vitticollis*). These larvae tunnel more or less spirally beneath the bark of living stems, not killing them outright but crippling them. However, the shrub thrives as dense thickets in spite of this injury. In dead stems were found medium-sized shiny oval weevils of a new species of Oodemas. There were caterpillars feeding in pith of dead stems from which the moth *Hyposmocoma chilonella triocellata* was reared.

Insects of Ohelo (*Vaccinium calycinum* and *Vaccinium peleanum*)

The first mentioned species of Vaccinium occurs commonly in clumps in the forest reserve as well as above. The leaves were badly eaten by the caterpillars of a red moth (*Phlyctaenia pyranthes*). None was reared, but the moths came abundantly to light. Berries were scarce and some of them were being eaten by the larvae of a moth, a species of Heterocrossa. None was reared, so the species was not determined. Bushes of *Vaccinium peleanum* were found common in the sparse scrub above the mamani forest, at an elevation above 8500 feet. Berries were more abundant and a few were found eaten similarly to those of the lower species, but no moths were reared. It no doubt would be the same as the species which infests ohelo berries of the Kilauea region: *Heterocrossa inscripta.* Many of the stems were found to have been injured by borers, and a few of the borers were found. They ate in the living stems and worked more or less spirally around the stem. From larvae in stems taken to the laboratory, one beetle was reared, which proved to be a new species somewhat related to a beetle that bores in Raillardia on the summit of Haleakala, Maui.

Insects of Tree Fern (*Cibotium chamissoi*)

This species of tree fern was plentiful in the jungle of the forest reserve. No insects were found feeding on the living ferns, but the stems of dead fronds were well populated with insects; some feeding on the decaying tissues of the stem;

some predacious on other insects; and others using the hollow stems as a retreat or hiding place. The most abundant insect feeding in these dead stems was *Proterhinus ferrugineus.* The slender brown weevil, *Pentarthrum prolixum,* which is generally abundant in fern stems everywhere, was very scarce. Another weevil, *Dryophthorus insignis,* was also scarce. A nitidulid beetle was common. Among the predators were seven species of carabid beetles: *Colpodiscus lucipetens, Mecyclothorax konanus, Metrothorax deverilli, Thriscothorax varipes, Colpocaccus hawaiiensis, Mecyclothorax* near *vulcanus, Thriscothorax* near *bembidioides.*

From all of the foregoing, it is seen that, in general, the forest of the region is not suffering significantly from insect attack. One insect common to the region, which has not been mentioned, is the Fuller's rose beetle (*Pantomorus godmani*), which is an immigrant insect, whereas all of the others that have been considered are native insects. The Fuller's rose beetle is an indiscriminate feeder. The beetles feed on the foliage of nearly every kind of tree, shrub, fern and herb. They have often been quite injurious to small seedling trees planted in the region.

It is significant to note that although there are quite a number of kinds of insects present whose habits are feeding on dead and decaying wood, no termites were found in the region. Any other regions where we have studied the insect relations to the trees, the large termite, *Neotermes connexus,* has been found inhabiting dead branches and logs of about every kind of tree. Whether the elevation was higher than where this termite exists, remains yet to be determined. It will be a problem of interest to ascertain just what is the upper limit in the distribution of this termite, which inhabits the native forests of all the islands, not, however, coming down onto the lowlands, though it has been found as low as about 500 feet on Oahu. It is also worthy of mention that none of the immigrant ants of the lowlands were found in the Nauhi region; also that a single specimen of the Chinese grasshopper was found on grass in the vicinity of the Nauhi nursery. It is rather remarkable that it should have reached this place so far from the coast regions where it has been known in grassy regions and cane fields only the past six years.

Leaf Scald Disease

Leaf Scald Disease of Sugar Cane in Hawaii

By J. P. Martin, C. W. Carpenter and D. M. Weller

CONTENTS

		Page
I.	Introduction	145
II.	History and Geographic Distribution	146
III.	Occurrence in Hawaii	152
IV.	Description of Symptoms	157
	Chronic Phase	157
	Acute Phase	166
V.	Histology	166
VI.	The Causal Organism	178
VII.	Inoculation Experiments	184
	On Oahu	184
	On Hawaii	187
	On Kauai	187
VIII.	Varieties Affected	189
IX.	Economic Importance	191
X.	Transmission	191
XI.	Control Measures	193
XII.	Summary	194
	Literature Cited	195

I. INTRODUCTION

Leaf scald, a vascular disease caused by *Bacterium albilineans* Ashby, is considered by plant pathologists to be one of the eight more important diseases of sugar cane. The other seven diseases of major importance are mosaic and streak (caused by so-called viruses), Fiji and sereh (possibly of virus origin), gumming (*Bacterium vascularum* [Cobb] Grieg-Smith), smut (*Ustilago scitaminea* [Rab.] Syd.), and downy mildew (*Sclerospora sacchari* Miy.).

Explanation of Plate: Manoa varieties affected with leaf scald disease.

A. and C. Portions of leaves of Manoa 185 and 160, respectively, showing the typical narrow white lines on blades and sheaths.

B. Longitudinal section of top of stalk (M. 160). Typical appearance of the red discolorations of the vascular bundles and portions of the adjacent parenchyma. The red discoloration is most conspicuous in the nodes.

D. Lower portion of stalk with side shoots illustrating symptoms of the chronic phase of leaf scald (M. 160). Etiolated portions of leaves, white lines on the leaves and internal red discolorations of the stalk are shown.

Leaf scald disease has been responsible for severe economic losses to the sugar industry in several districts of Australia, causing the elimination of the desirable Mahona variety and preventing the culture of other promising varieties. In Java, "Gomziekte," now considered to be leaf scald, has caused serious damage on young plant cane and, as in Australia, has curtailed the spread of desirable commercial canes.

Hawaii has remained comparatively free from the more serious cane diseases as graphically shown in the following chart. Only two of the above-mentioned eight major diseases are known to occur here, namely, mosaic and leaf scald. The former disease, then known as Yellow Stripe, was first recorded here in 1908 by Lyon (17, p. 2), who identified it with "Gele Strepenziekte" of Java. Leaf scald was first identified here in December, 1930, by the authors, although, according to the observations of several plantation managers, it has been present sporadically for a decade or longer. Its occurrence has been noted thus far only in variety test plots. While no commercial losses have been experienced, the disease is regarded as potentially important.

The object of this first paper on the subject is to present the outstanding characteristics of leaf scald disease not only as it occurs in Hawaii, but as it occurs in other countries as well. Many illustrations of the features of the disease and growth habits of affected canes, gross and microscopic diagnostic symptoms and characters, supplement the description. It is hoped that this paper will serve to acquaint the personnel of the sugar industry with the disease so that it may readily be recognized.

Leaf scald disease is discussed in this paper with special attention to the following considerations: History and geographic distribution; gross and microscopic symptoms; distribution of *Bacterium albilineans* in the tissues; inoculation experiments; varieties affected and resistance of varieties; economic importance; transmission and means of control.

II. HISTORY AND GEOGRAPHIC DISTRIBUTION

Our knowledge of leaf scald disease is largely due to Dr. G. Wilbrink, directress and pathologist of Cheribon Sub-Experiment Station, Cheribon, Java, and to D. S. North, pathologist for the Colonial Sugar Refining Company, Ltd., Sydney, Australia.

In 1915, Groenewege (12) erroneously concluded that this disease, known in Java as Gomziekte, and the Australian gumming disease, caused by *Bacterium vascularum* Cobb, were identical. "Gomziekte" became known in other countries as "Java gumming" disease, which led to further confusion with the true gumming disease.

In 1920, Wilbrink (29) published a very comprehensive paper on Gomziekte, the Java gumming disease, and showed conclusively that it was distinct from the true gumming and sereh diseases. North and Lee (20), in 1924 discussed the

FIG. 1.

A stalk of the variety Manoa 185 badly affected with leaf scald disease (chronic phase). Note the development of side shoots and drying of top. This plant exhibited both the red vascular bundles in the stalk and the white stripes of the leaves (July 7, 1931).

similarity between the leaf scald disease of Australia and Java gumming disease and affirmed the conclusion of Wilbrink that Java gumming was distinct from true gumming disease. North (21, p. 9) concluded that the Javanese gumming disease and the Australian leaf scald disease are in all probability identical. The simultaneous studies by Wilbrink (*loc. cit.*) in Java and North (21) in Australia, the research of each being unknown to the other, resulted in practically identical accounts of the symptoms of leaf scald and detailed descriptions of the causal organism.

The history of this disease in Java may be summarized from the account by Wilbrink as follows:

Prior to 1913, this disease was referred to as Hundred Brown disease because a variety known as Hundred Brown was primarily concerned. Later the disease was considered the same as Australian gumming disease following the publication of descriptions of this disease by Cobb (7, 8 and 9). In 1915, Groenewege (12) published a paper under the title "The Gum Disease of Sugar Cane Caused by *Bacterium vascularum* Cobb," and again in 1917 a paper (13) entitled "The Gum Disease of the Sugar Cane and the Means of Checking It." Wilbrink (*loc. cit.*, p. 1401) excused a reopening of the subject in the following statement: "The reason is that it is not shown in the above-mentioned treatises that the cause of gumming disease has been found, or that the proper means of dealing with it are proposed."

Wilbrink refuted the conclusion of Groenewege that Gomziekte and Australian gumming disease were the same, and avoided the assumption of other Java investigators that Gomziekte was a form of sereh. Her conclusion that Gomziekte was distinct from Australian gumming disease was based on experimental evidence and critical comparisons of the symptoms of the two diseases, as well as careful studies of the causal organism. Her conclusions were confirmed by North (21). Following the publications of Wilbrink and North various writers noted the occurrence of this disease in other countries.

The history of leaf scald disease in Australia and Fiji was summarized by North (22, p. 1) as follows:

> In Australia, its presence has been traced back with certainty to 1911, and it seems likely that it was introduced some time prior to 1900, along with cane plants from either New Guinea or Java. This is strongly suggested by the early history of Mahona (No. 22 of Tryon's 1896 collection of New Guinea canes), which, although a splendid variety in other respects, was said to "mature too early and die off," particularly in tropical districts. It is still liable to "die off" in this manner, but only as the result of leaf scald disease, to which it is one of the most susceptible varieties known.
>
> In these early times, the disease was probably widely distributed through the cane areas of Australia and Fiji, because Mahona apparently failed through "dying off" in practically all districts except the Richmond and Tweed Rivers of New South Wales. In these two districts it yielded highly profitable crops, being widely grown for many years and becoming the main standard variety for a time. They apparently escaped infection by some chance However, leaf scald was introduced from the Clarence to the Richmond in a consignment of 46 tons of N. G. 16 cane plants in 1912, and seems also to have been introduced to the Tweed

FIG. 2.

Chronic form of leaf scald disease on Manoa 160. Note the presence of side shoots and white stripes on their leaves. The leaves on the top of this stalk manifested definite symptoms (April 25, 1931).

by some unknown means about the same time. In 1915-1917 it became conspicuous in the Mahona crops in both these districts, and during the next few years caused very severe crop losses. . . . On this account the variety finally had to be discarded, or "ran out," as the farmers say, and more resistant kinds grown in its place.

It is likely that leaf scald similarly caused not only Mahona but also other susceptible varieties to "run out" in earlier times in many other districts, but on this point no definite records are available. This is strongly suggested, however, by the fact that the standard varieties now cropped in Australia and Fiji are for the most part highly resistant. Also the planting of Clark's Seedling (H. Q. 426), the Gorus (N. G. 24, N. G. 24A, N. G. 24B) and Pompey (7R428) has lately been seriously curtailed in certain districts (e. g., Mossman, Cairns, Johnstone River, Rarawai) owing to its ravages. All of these varieties, too, may be classed as moderately resistant, all being much less susceptible than Mahona.

Hurried surveys made by the writer in 1911 and 1915 have served to establish its prevalence in those times in the Cairns, Johnstone River, Herbert River and Mackay districts. Some suspicious cases of Clark's Seedling suddenly dying off (not definitely diagnosed as leaf scald, however) were also observed in the Childers district.

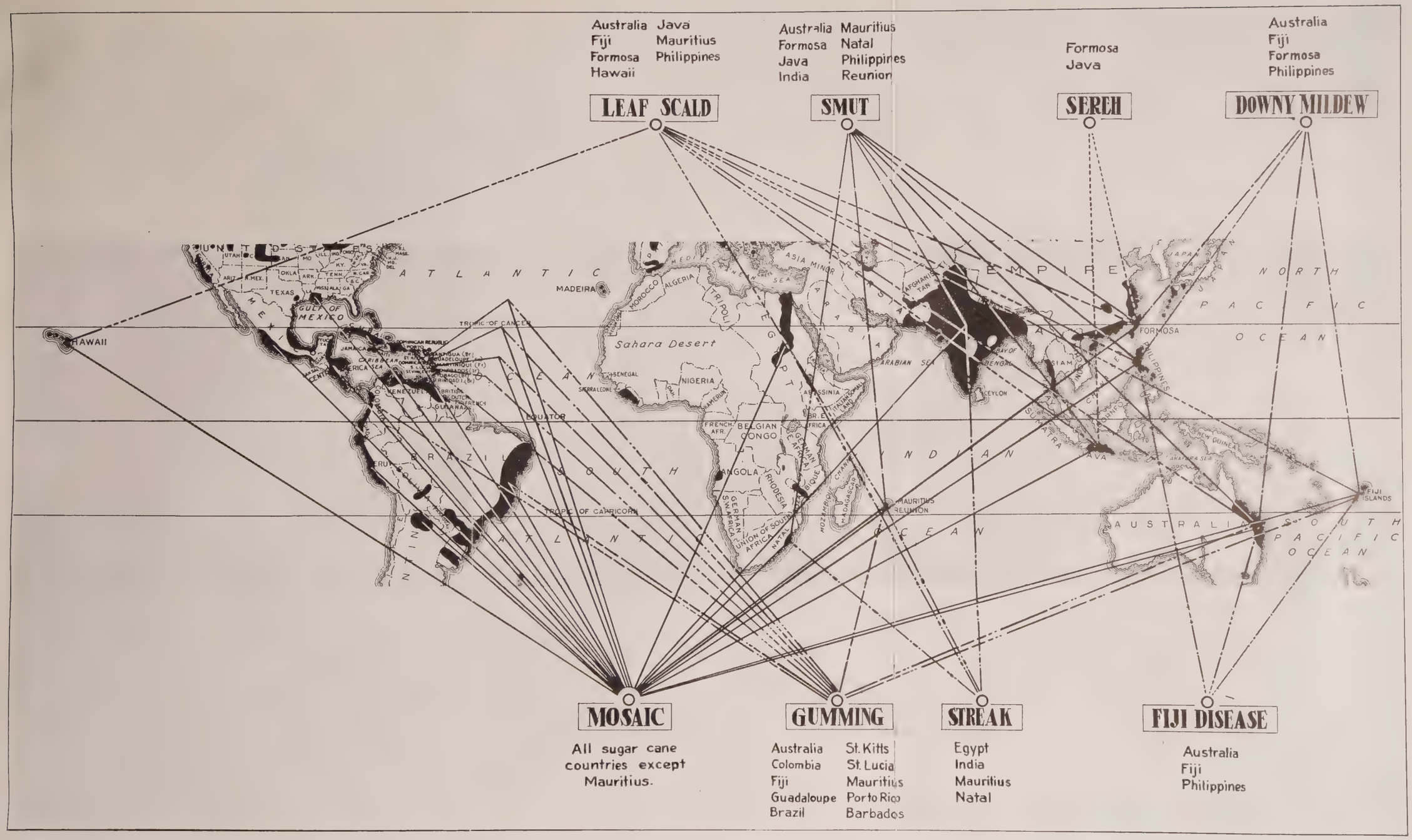
In the Philippines, Lee (14), 1921, described a red vascular disease of sugar cane which was observed in several districts. Lee states (pp. 432, 433):

There has been observed at Lamao, Bataan; Alabang, Rizal; Carmencita, Pampanga; in Mindoro and sparsely distributed throughout Occidental Negros a disease which we are calling red vascular disease characterized by a wilt of the leaves and by reddened vascular bundles. The disease is distinct from the published description of sereh in that there is no mention of a wilt of the leaves in the case of sereh, nor is there in the case of this Philippine disease the profuse stooling of the affected canes as described for sereh in Java. The disease is most common on H 109, altho it has also been observed on Louisiana Striped and Negros Purple. Inasmuch as Negros Purple is said to be very resistant to sereh in Java, this constitutes another reason for believing it to be distinct from sereh. The disease is also quite distinct from wilt and red rot, either of which from the written description might be confused with this trouble.

Lee (15), after visiting Java in 1923, concluded that the Philippine red vascular disease and Java gumming were identical.

North and Lee (20), 1924, in Honolulu, Hawaii, after carefully studying preserved specimens and photographs, discussed the similarity between leaf scald disease of Australia and the Java gumming disease described by Wilbrink (29). These investigators in confirming the view expressed by Wilbrink commented as follows: "The Java gum disease described by Miss Wilbrink is decidedly different from Cobb's gumming disease of sugar cane and since it may lead to confusion to continue with such a name, it seems desirable to adopt the rather descriptive name leaf scald as used in Australia for this trouble."

In Formosa, the disease was first observed in 1918 on canes imported from Java, according to Dr. T. Miyake, director and pathologist, Government Research Institute, Taihoku, Formosa, in personal communication. It was named "Haku Jyo Byo," meaning white stripe disease. Symptoms of leaf scald disease have been noted in the various cane-growing districts of Formosa but the economic losses have been considered of minor importance.



SHOWING THE GEOGRAPHICAL DISTRIBUTION OF THE MAJOR SUGAR CANE DISEASES OF THE WORLD

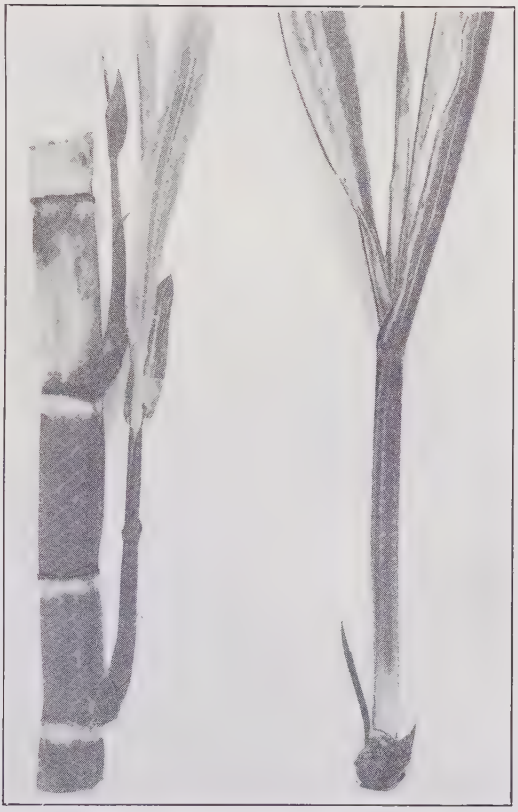


FIG. 3.

Typical symptoms of leaf scald disease on Manoa 160. Side shoots with white lines on the leaves are shown (February 26, 1931).

The disease was recorded for the first time in Mauritius in 1928 by Tempany (*27, 28*), where it undoubtedly had existed for many years previous to this date but had been confused with gumming disease caused by *Bacterium vascularum* Cobb. Leaf scald is now known to be widespread over the island. It attacks chiefly White Tanna and Striped Tanna canes and results in losses both in field and factory. Experiments have been conducted wherein losses of from 5 to 11 per cent of cane weight occurred and the sucrose content reduced as much as 16 per cent. White Tanna is tolerant to the disease and fair yields are being obtained from this variety under favorable climatic and cultural conditions. The disease not only affects the standing cane but greatly inhibits the germination of planted cuttings and ratoons.

Christopher and Edgerton (6) mention a disease of cane in Louisiana characterized by white stripe symptoms which resemble those of leaf scald. No organism was isolated and the disease appeared of little importance.

III. OCCURRENCE IN HAWAII

Occasionally, during the past eight years, symptoms suggestive of leaf scald disease of sugar cane have been observed and studied. In the early part of 1930 several new local varieties on the island of Kauai manifested the disease symptoms described in this paper. In a number of instances free-hand sections of fresh material from affected stalks and leaves showed the presence of motile rod-shaped bacteria within the vascular bundles.

In September, 1930, Royden Bryan, of the agricultural department of this Station, collected diseased specimen material of the variety Manoa 160 at Onomea Sugar Company on the island of Hawaii and forwarded it to the pathology department for diagnosis. This material exhibited the typical external and internal symptoms of the chronic phase of leaf scald disease.

The occurrence of a large number of diseased stools in the several plots of Manoa 160 at Onomea provided abundant material for observation and afforded an opportunity to identify the disease. The cane in these plots consisted of plant as well as first and second ratoons, about six to eight months old. The plots were in wet localities at elevations of 800 to 1200 feet.

It was evident at once that the diseased cane manifested all of the symptoms typical of the chronic phase of leaf scald disease and the symptoms of the acute phase were present on an occasional stalk. The symptoms characteristic of leaf scald are described in detail on pages 157-166. At Onomea, the leaf stripping, development of more or less etiolated "lalas" (side shoots) and suckers, as well as the internal vascular discolorations typical of leaf scald disease, were conspicuous features.

The history of the individual plots indicated that the disease had been transmitted from plot to plot by infected cuttings. In an upper field of young plant cane there was some evidence indicating that certain of the cuttings had acquired the disease from infected knives. This area had been rogued several times

FIG. 4.

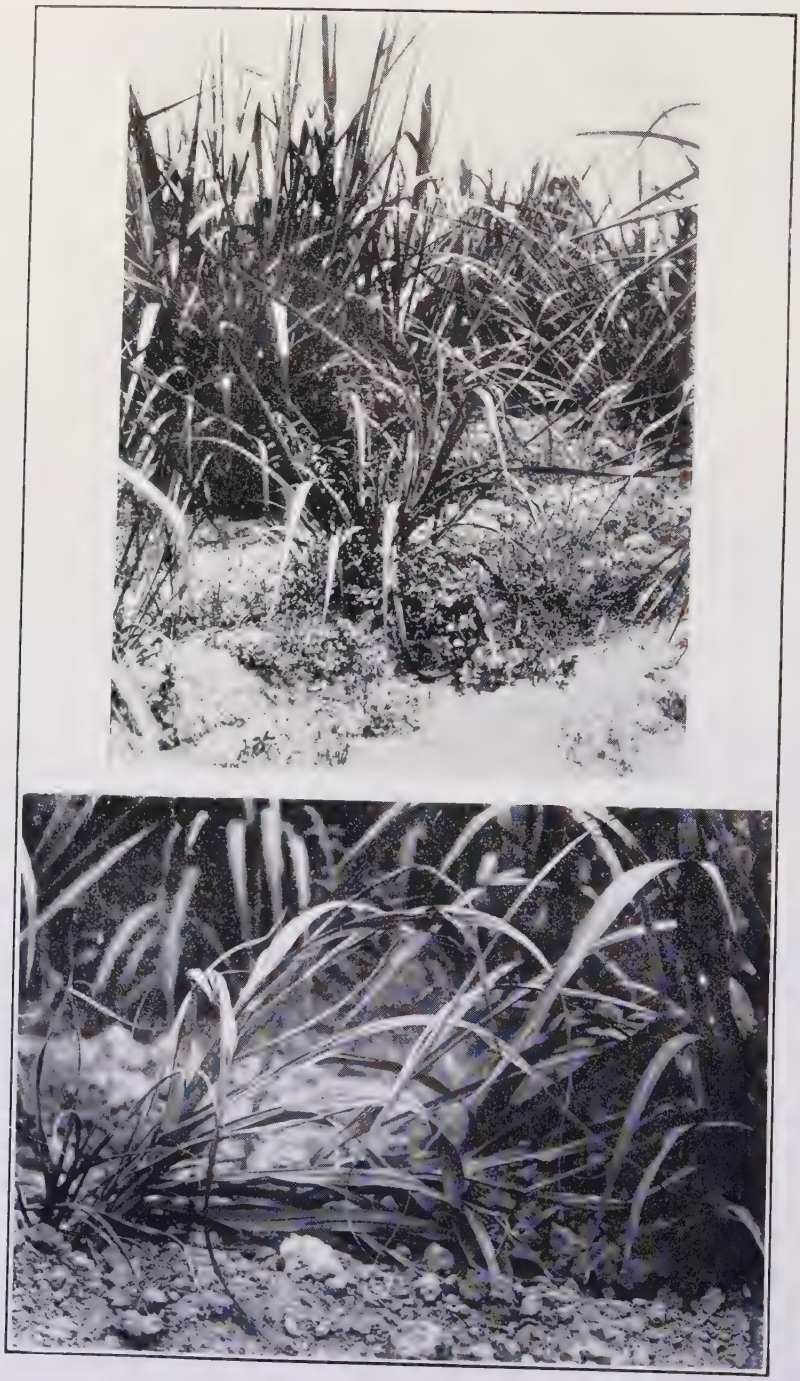
A. E. K. 28 cane affected with leaf scald disease (Cheribon Sub-Experiment Station, Java, 1929).

B. Showing the development of side shoots on stalk of Badila cane (Broadwater, N. S. W., Australia, 1929).

C. Shoot of Badila cane showing characteristic upward curling and withering tips of leaves (Innisfail, Queensland, Australia, 1929).

D. Illustrating the occurrence of numerous side shoots (Badila cane, Innisfail, Queensland, 1929).

A



B

FIG. 5.

A. A stool of H 109 cane in the foreground affected with leaf scald. Note depressed growth in comparison with the healthy cane in the background. (Tarlac, Luzon, P. I., 1929.)

B. Leaf scald disease on the variety Pampanga Red. The older leaves were beginning to wither, while the younger leaves were chlorotic and showed typical white lines. (Tarlac, Luzon, P. I., 1929.)

to eliminate diseased stools. However, a number of slightly affected stools remained and since the cane was small, having grown slowly as a result of the unfavorable wet weather which prevailed in the summer of 1930, the planted cuttings could be easily pulled from the soil. Only the leaf striping symptoms were present and in general only one of the several shoots in a stool appeared to be diseased. Many of these stools were pulled out and examined. It was observed in almost every case that the one affected shoot on the cutting was the one developed from the uppermost eye. While this observation might indicate a habit of the diseased cane, it seemed rather to indicate infection from the cut end of the seed piece.

A preliminary examination, microscopically, of free-hand sections of the affected tissues of the leaves and of the growing points of the stalks, as well as of bacterial smears made from such tissues, indicated that the disease was caused by bacteria. The presence in the affected tissues of motile bacteria which agreed in shape and size with the causal organism of leaf scald as described by Wilbrink and North was observed. A corresponding plugging of the vessels of the vascular bundles was conspicuous. Incidentally, it may be of interest that pure cultures of the first isolations, i. e., the series 438, 441 and 443, in subsequent inoculation tests proved to be the pathogen (see Fig. 21, Table II and p. 187).

The gross symptoms and the results of the observations, microscopically, when considered in conjunction with the very complete descriptions of leaf scald disease by Wilbrink and North, indicated beyond reasonable doubt that the disease affecting the Manoa 160 and other varieties in Hawaii was leaf scald.

In order to determine whether or not the disease attacking Manoa 160 was infectious and could be mechanically transmitted, a series of direct inoculations was carried out by Martin at Onomea, December 22, 1930. An infusion was prepared by macerating the growing points of diseased plants of Manoa 160 in sterile, distilled water. The growing points used showed reddened vascular bundles, one of the symptoms of the chronic phase of leaf scald disease. On the leaves of the plants from which the diseased growing points were selected, very sharply defined white lines, another symptom of the chronic phase, were present. The macerated material was next filtered through several thicknesses of cheesecloth so that the larger particles of plant tissues were removed from the infusion.

Healthy plants of Manoa 160 were selected in the field at Onomea for an inoculation test. First a number of plants were injected hypodermically near the growing point with sterile, distilled water to serve as controls. Then another series of selected healthy plants were inoculated near the growing point with the infusion. Within three weeks symptoms corresponding to those of the chronic phase of leaf scald disease began to develop on the plants inoculated with the infusion (Fig. 6). The control plants remained healthy. These preliminary tests demonstrated that an infectious disease was affecting the variety Manoa 160. The results of these tests are included in Table II.

In the meantime four varieties of susceptible cane were being grown in a quarantine house at Honolulu to provide material for inoculation tests with pure cultures of the suspected pathogen. Although it was evident that the disease was

FIG. 6.

White lines, typical of leaf scald disease, extending from the leaf blades onto the leaf sheaths. These lesions developed on healthy Manoa 160 as a result of inoculations with infusion from diseased cane. (February 26, 1931.)

leaf scald, bacteria closely resembling *B. albilineans* Ashby having been isolated in pure culture, it was necessary to produce the disease by inoculation with the suspected pathogen, and prove its identity with the causal bacterium of leaf scald disease, to complete a positive diagnosis. Carpenter, in December, 1930, had demonstrated the presence of slender, short, rod-shaped bacteria in the affected tissues of Manoa 160 and H 109 collected respectively at Onomea Sugar Company, Hawaii, and Oahu Sugar Company, Ltd., Oahu. Several strains (439B, 439X) of one type of bacteria isolated from the mentioned H 109 cane proved to be the pathogen in inoculation tests conducted in the quarantine house at Honolulu. Subsequent isolations by Martin and Carpenter from Manoa 160 collected at Onomea yielded many additional pure cultures of bacteria similar to *B. albilineans*. Such bacteria proved capable of producing the typical symptoms of leaf scald disease when healthy stalks of Manoa 160 were inoculated at Onomea Sugar Company. These experiments are discussed in more detail on page 187 and the results are included in Table II. These studies showed conclusively that leaf scald disease occurred in Hawaii.

While the inoculation tests were being conducted a survey of all of the plantations of the Islands was made in order to determine the distribution of the disease. In addition to the plots mentioned at Onomea a few sporadic cases of the disease were found in the Hilo District on the island of Hawaii; a number of cases were found in several small plots of seedling canes at Koloa, Kauai; none were found on Oahu other than the two stools mentioned on page 185; and no evidence of the disease was found on the island of Maui. In order to confirm the diagnosis of the disease on Kauai, Weller made a series of isolations and conducted inoculation tests at Koloa. These tests are discussed in detail on page 187 and the results included in Table II.

IV. DESCRIPTION OF SYMPTOMS

Wilbrink (*loc. cit.*) and North (21) recognized two distinct "phases" of leaf scald, namely, the chronic and the acute. As late as 1919, according to North, the two phases were regarded in Australia as two separate diseases, but following a more intensive study they were shown to be two forms of the same disease. In fields affected with leaf scald it is possible to observe both phases, one phase frequently grading into the other. For convenience each form will be described separately.

Chronic phase: The earliest symptom of the disease is recognized by the presence of elongated, narrow, white stripes on the leaf blade. These stripes may extend the entire length of the leaf including the leaf sheath, or may be only a few inches in length before they blend into the normal leaf color. The stripes vary in width from a fine line to one-eighth of an inch, although occasionally they may be one-quarter of an inch in width. These narrow stripes on cane leaves are illustrated in Fig. 3 and in the colored plate opposite page 145. The color of the stripes varies from pure white to a yellowish white. Occasionally minute reddish-brown spots are scattered throughout the chlorotic tissue, or a thin red line extends up the middle of the white streak. These spots are due to necrosis of the tissue, which

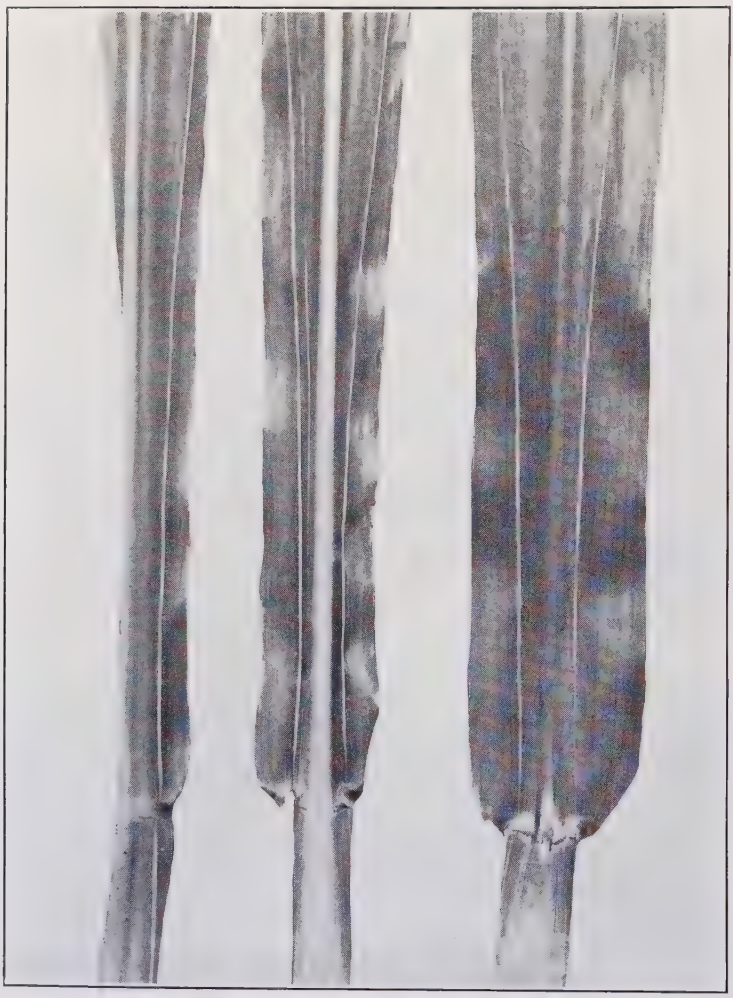


FIG. 7.

The narrow white lines characteristic of leaf scald extend onto the leaf sheaths. These lesions were produced by inoculating healthy plants (Manoa 185) just below the growing point, with a pure culture of *Bacterium albilineans*. (July 7, 1931.)

FIG. 8.

The two stalks of Manoa 186 at the left illustrate the wilted and inward curved leaves characteristic of the acute phase of leaf scald. The side shoots are more characteristic of the chronic phase of the disease. At the right is shown a healthy stalk of this variety. (July 7, 1931.)

FIG. 9.
The development of side shoots on diseased stalks of Manoa 185. The tops of these stalks showed the acute phase (wilt) of leaf scald. (July 7, 1931.)

in advanced stages results in an irregular reddening of the lesion. A partial or complete etiolation of the cane tops may be present, especially in young ratoons. The stripes follow the vascular bundles of the leaves and sheaths and may include one or more bundles. The margins of the stripes are sharp and well defined. The reason for their sharply defined edges is discussed under the histology of the disease on page 174. The stripes are usually visible on both sides of the leaf but in some cases they may be restricted to either surface. As the lesions mature they become broader, especially on the old leaves; they sometimes lose their sharpness of outline, becoming more diffuse. The final development is the dying of the tissue involved, which may take place at any point in the streak but usually starts at the margin of the leaf blade and travels downward. These stripes may be found on the very young leaves of the spindle which are as yet unrolled.

As already mentioned, the characteristic stripes often extend onto the leaf sheath and may assume a purplish color. These symptoms are shown in Figs. 3, 6 and 7, as well as in the colored plate. One or more streaks may be present on the leaf blade or leaf sheath, according to the severity of infection.

A literal translation of the name of the causal agent of leaf scald disease, *Bacterium albilineans,* signifies a bacterium producing white lines; this in itself is highly descriptive of the outstanding symptom of the disease. On very young cane such straight, narrow white lines are the only diagnostic symptom.

However, on older cane other definite symptoms are to be considered. The affected stalks may produce side shoots, locally known as "lalas," as illustrated in Figs. 1, 2, 4, 8 and 9. At first only one or two side shoots develop, followed by others both above and below this point, and in a short time a large number of "lalas" will have been formed. In a badly diseased stalk it is not uncommon to find that every bud on the stalk has sprouted. The leaves of these side shoots also frequently manifest typical white streaks, as described above, which are extremely useful for diagnostic purposes, especially if for any reason the stripes on the cane top have been obliterated due to the death of the top.

The side shoots or "lalas" are as a rule very weak, the young leaves being more or less etiolated; this condition is illustrated in the colored plate. These side shoots, which seldom attain a length of over 18 to 24 inches, soon wither and die. At the base of a diseased stool numerous weak suckers develop and the symptoms already described may occur on this type of growth.

Upon splitting an affected stalk, bright red longitudinal lines or streaks are visible, particularly at the nodes (see colored plate; and Figs. 10, 11 and 12). This discoloration is due to a reddening of the vascular bundles and adjacent tissues which have been invaded by the causal organism. The discolored bundles are more numerous at the nodes but they may extend through the internodes. Such reddened fibres are more conspicuous in the more mature portion of the stalk in the nodes from which "lalas" have developed. They are also found near the growing points of the main stalks as well as in the side shoots and suckers. These symptoms, shown in the colored plate, are discussed in more detail on page 170.

In summarizing, the important symptoms of the chronic phase of the disease are as follows: (1) the presence of whitish narrow stripes on the leaf blade and leaf sheath, withering of leaf tissue at the distal end of the stripes and more or less

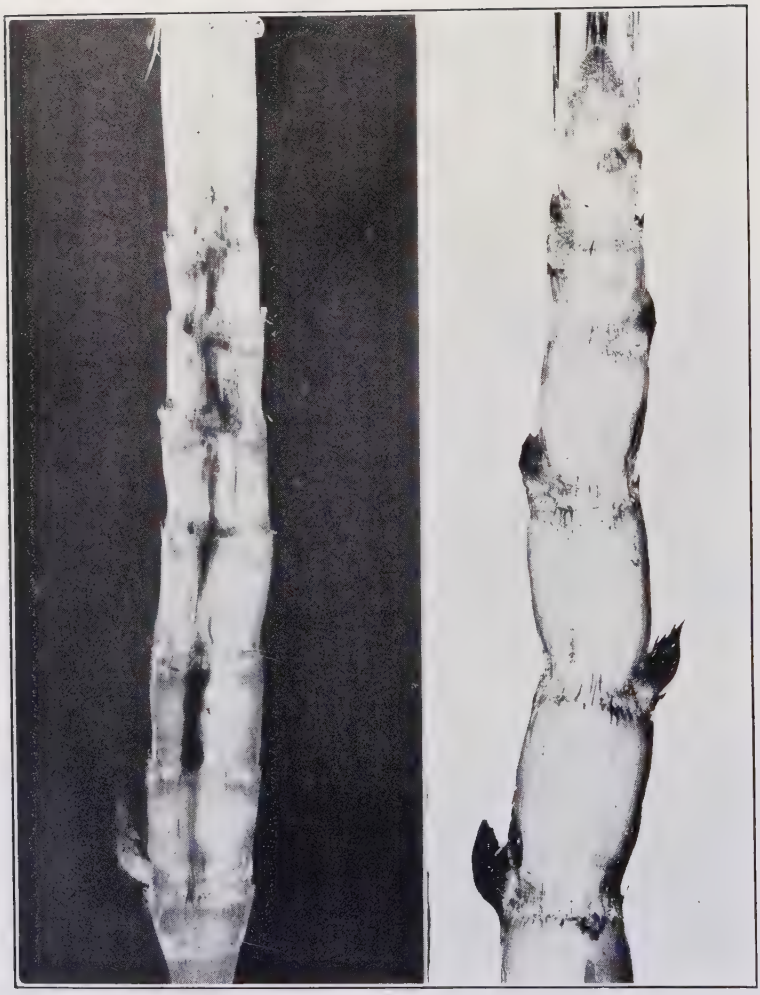


FIG. 10.

Internal symptoms of leaf scald disease (Manoa 185). Red discoloration of the vascular bundles is most conspicuous at the nodes. Red discolored tissues are conspicuous in the upper nodes near the growing point. Lysigenous cavities also are shown. (July 7, 1931.)

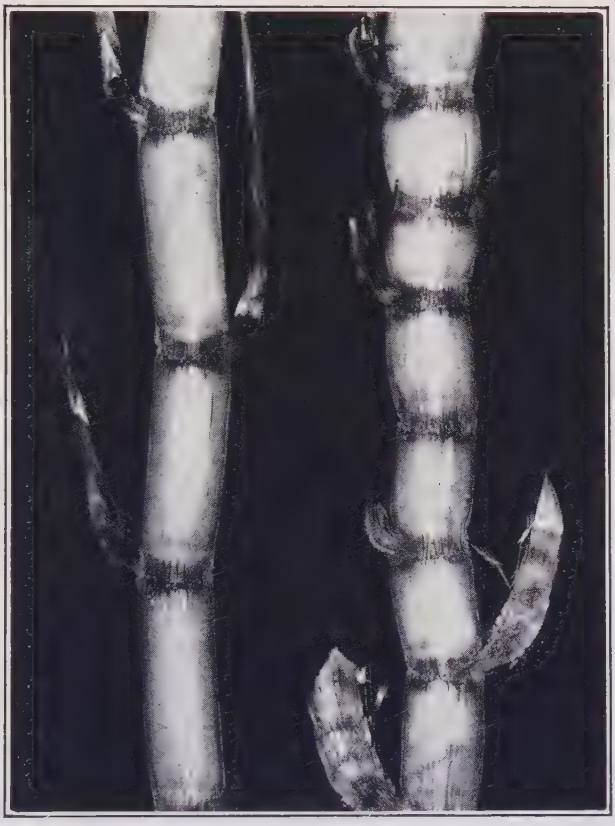
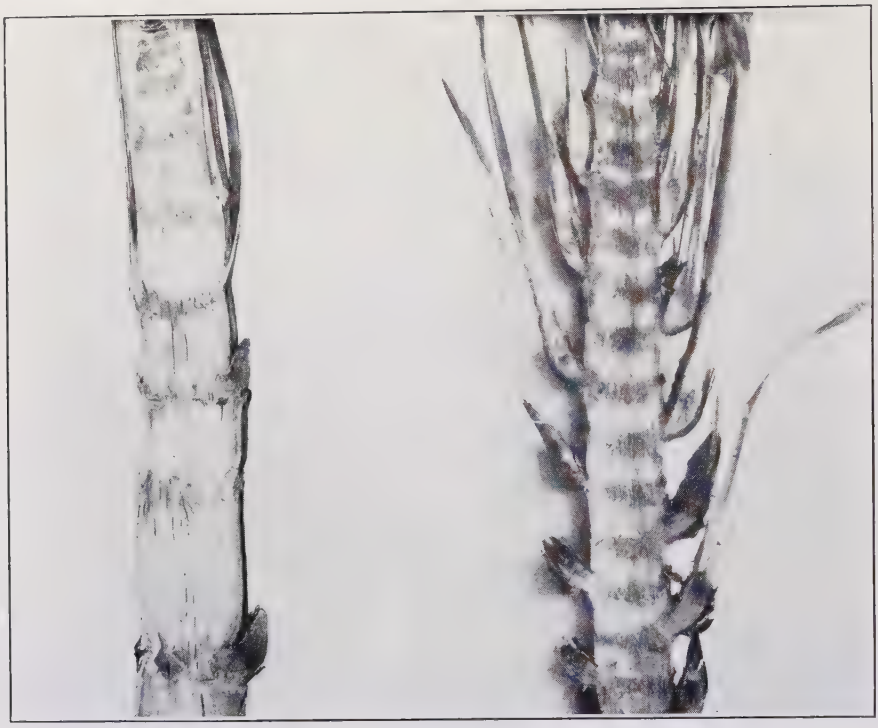


FIG. 11.
Split stalks of diseased Manoa 185 showing red discolorations particularly at the nodes. (July 7, 1931.)



A B

FIG. 12.

A. Longitudinal section of a stalk of E. K. 28 showing reddish vascular bundles which are more pronounced at the nodes. Such discoloration is highly characteristic of leaf scald disease. (Cheribon Sub-Experiment Station, Java, 1929.)

B. Leaf scald disease on Badila cane. Longitudinal section showing discoloration of vascular bundles at nodes and development of side shoots. (Innisfail, Queensland, Australia, 1929.)

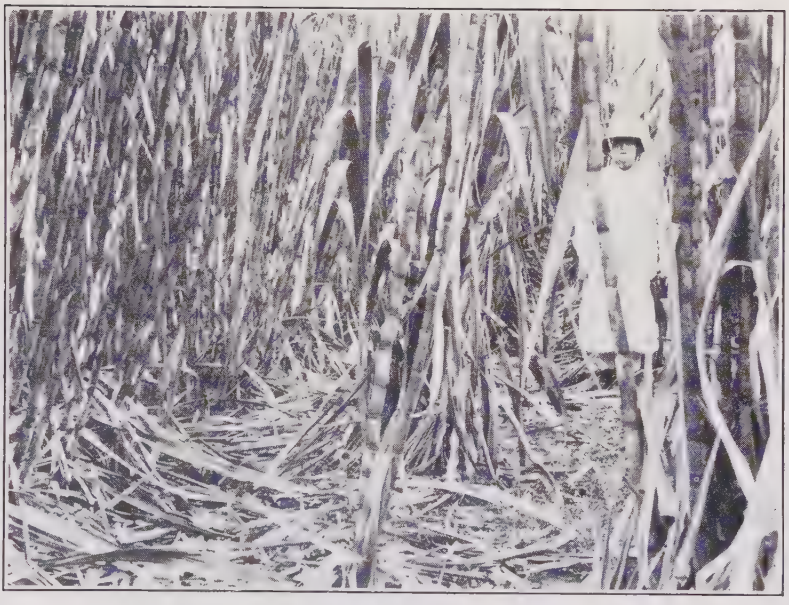


FIG. 13.

The stand of cane on the left was grown from healthy cane cuttings which were cut with a sterilized cane knife. The open stand on the right was grown from healthy cane cuttings which were cut with a cane knife used previously to cut diseased cane. Many stools failed to grow as indicated by the irregular stand. Dr. G. Wilbrink is in the background. (Variety E. K. 28, Cheribon Sub-Experiment Station, Java, 1929.)

etiolation of the leaves; (2) the production of side shoots or suckers in affected stools with the characteristic white stripes on the leaves, or with white leaves; and (3) the reddish discoloration of the vascular bundles, particularly at the nodes.

Acute Phase: The acute phase of the disease is quite conspicuous in the field and is characterized by a sudden or acute wilt of the plants, especially during periods of dry weather or when the cane approaches maturity. Individual stalks, entire stools or even large areas may develop this form of the disease. North (22, p. 19) states regarding the acute phase:

> Many whole stools and parts of other stools, sometimes even whole fields, may suddenly wither and die in a most alarming fashion. The wilting takes place just as if the canes attacked were suddenly deprived of their roots, neighboring unaffected canes meanwhile remaining green and of vigorous healthy appearance. The effect on the crops resembles that caused by the Queensland cane grub, so much so that farmers in North Queensland sometimes attribute to grubs damage which is really caused by leaf scald.

Bell (3, p. 21) comments as follows on the diagnosis of this phase of leaf scald:

> In the acute form it is often difficult to make a positive diagnosis and to do this it is necessary to search the base of affected stools for the side shoots and suckers which bear the very narrow white stripes upon the blades and sheaths of the leaves.

Plants manifesting symptoms of the acute phase seldom exhibit the typical white stripes on the leaves of the cane top.

In Hawaii the chronic phase of the disease has been most commonly observed although several cases of the acute form have been found. An acute form of leaf scald disease on Manoa 160 is shown in Fig. 8. The upward curling of the leaves is characteristic of plants manifesting this phase.

V. HISTOLOGY

The most conspicuous of the symptoms of the chronic phase of leaf scald disease, as described on page 157, is that of the narrow, white or cream-colored lines with sharply defined margins running parallel to the vascular bundles of the leaves and sheaths. At a certain stage in the development of these white lesions appear very small pink to red-brown dots, which may become confluent, forming a very narrow, pinkish line throughout the center of the lesion. The direction and appearance of these lesions suggest that one or more of the vascular bundles have been affected.

When transverse sections of such lesions are examined it is seen at once that a vascular disease is being dealt with, for the tracheae, or water-conducting tubes of the bundles, are seen to be wholly or partly occluded with a gum-like substance, which varies from a pale to a deep brown color (Fig. 14).

It is hoped that the following histological study may facilitate the diagnosis of the disease, especially in obscure cases, and also contribute to a better understanding of its fundamental nature as well as to the related problems of its transmission and control.

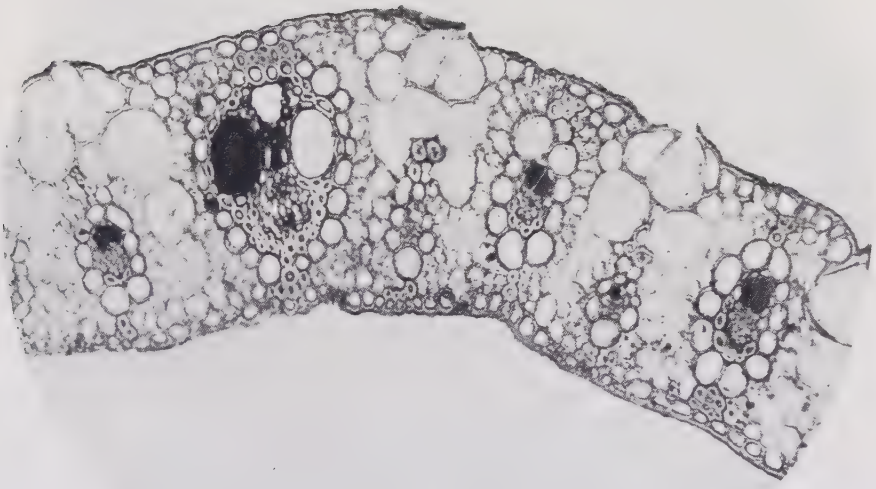


FIG. 14.

Transverse section through one of the narrow white lines on a leaf of a cane plant of the variety Manoa 160 affected with leaf scald disease, showing the vessels, or water-conducting tubes, of a number of the vascular bundles to be occluded by a gum-like substance (X 147).

Methods and Materials

Fresh as well as fixed and stained material of both phases of the disease was used in this study. Sliding microtome sections of fresh material mounted in water offered a convenient method of studying the living pathogen *in situ*. Material was killed and fixed in formalin-acetic-alcohol (5), Bouin's picro-formol (16), Allen's "B-15" (1), Meves' fluid (10), Milovidov's chromic acid—potassium dichromate—formalin fluid (11), by Champy-Kull's modification of Altmann's method and of Benda's method (18), in Regaud's fluid (10), and in Murray's Formol-Müller (18).

Sliding microtome sections were made from some of this preserved material just before it was run up through the alcohol series for embedding, stained and mounted in glycerine. After the material was embedded in paraffin, serial sections were made and stained by the same methods as were the sliding microtome sections.

A number of staining techniques were used to demonstrate both the general anatomical features of the host tissues and to stain the causal organism in the tissues. For the former safranin combined with either Delafield's or Haidenhain's haematoxylin, with anilin blue, or with light green was useful. Flemming's triple stain was excellent for this purpose.

Because the gum in the xylem cells of the bundles was always stained heavily by the safranin, destaining with acid alcohol had to be done quite precisely. Unless this was done the details within the gum mass were obscured. The nicest detail within the gum mass was always obtained by Murray's method of using Haidenhain's haematoxylin for staining mitochondria and bacteria.

A number of attempts were made to demonstrate the pathogen *in situ*. This proved rather difficult to do. Ziehl's carbol-fuchsin was first tried according to North's suggestion (21, p. 33), but for some unknown reason this method failed not only when preceded by Bouin's picro-formol, but when following formalin-acetic-alcohol, Allen's "B-15," Regaud's and Meves' as well. Neither Champy-Kull's method nor those suggested by Dufrenoy (10, 11) succeeded. The most satisfactory method proved to be that of Murray (18). (See Figs. 15, A, B; and 16.) This method proved to be not only simple in technique but precise in its staining and the color differentiation of the host tissues was excellent for the purpose of making photomicrographs.

The following stains were used: Safranin*† and Anilinblau, alc.† [Lot No.] 210, from Dr. G. Grübler & Company, Leipzig; Fuchsin Basic†, Lot No. 765 and Orange G—Crystals*†, from The Coleman & Bell Company, Norwood, Ohio; Hematoxylin C. P., Certification No. FH 7, from National Aniline & Chemical Company, Inc., New York, N. Y.; and Gentian Violet*† from The Harmer Laboratories Company, Philadelphia, Pa.

---

* Lot number not available.

† Dye content not available.

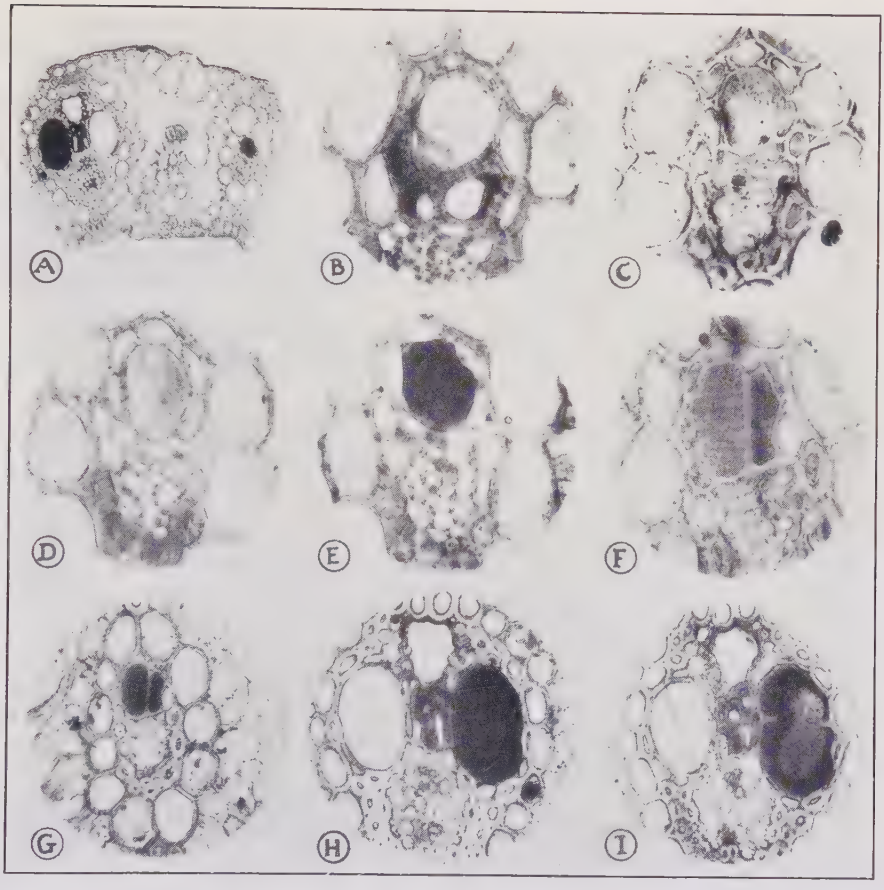


FIG. 15.

Transverse sections of vascular bundles of cane leaves affected with leaf scald disease: A, showing one of the vessels, or water-conducting tubes, of a large rhomboid bundle to be normal while another vessel of the same bundle is occluded with a dark, gum-like substance (X 90); B, the amber-colored gum-like substance, in which bacteria can be distinguished, beginning to invade a vessel of one of the small, round bundles (X 534); C, a vessel of a bundle similar to that shown in B in which the amber-colored gum-like substance containing distinguishable bacteria has completely occluded the invaded vessel (X 534); D and E, vessels of bundles similar to the ones shown in B and C but at later stages after occlusion, as indicated by the successively darker colors of their occluding gum masses and the absence of distinguishable bacteria (X 534); F and G, occluded vessels of medium-large, oval bundles (F, X 534; G, X 237); H, a larger view of one of the large rhomboid bundles (See A) showing the well-developed lysigenous cavity and the total occlusion of one of the vessels with gum (X 237); I, a bundle similar to the one shown in H (See also Fig. 18). The lysigenous cavity is well advanced. The gum mass of the occluded vessel shows a dark peripheral area with a relatively lighter central area. The remains of a former cross wall, apparently destroyed by the invading bacteria, are seen. The cells lying between the two large vessels and two small areas of the phloem (also seen in H) are discolored (X 237).

Host Tissues Affected

Xylem

When either fresh or fixed and stained sections of lesions of plants affected with leaf scald disease are examined it is readily apparent that there is a total lack of hyperplasia of the affected tissues and that the chief effect of the disease on the tissues is that of the occlusion of the vessels of the bundles with a gum-like substance (Figs. 14; 15, A, E, G, H, I; 17; 18). This gum and the progress of its formation in the xylem cells, whether of the bundles of the leaves, sheaths, or stem, tells much of the story that is to be told about the effects of the disease on the host tissues. In the more advanced stages of the disease, pockets of this gum may be formed also in the parenchyma outside of the bundles, especially at the growing point.

If fresh sections from the advancing area of a very young lesion of a leaf or sheath are examined, it will be seen that as yet no gum has been formed in the xylem cells. Instead, these cells are seen to be filled with rapidly moving bacteria. The first impression one has upon viewing these organisms is that they are too large to be the causal organism of the leaf scald disease. But if one watches carefully sooner or later individual bacteria, whose movements have slowed up, may be singled out. With the aid of an ocular micrometer the size of such organisms was estimated to be approximately 1.0 micron by 0.5 micron. This size compares favorably with the measurements made by North (21) and Wilbrink (*loc. cit.*) as well as with those by Carpenter as given in this paper. The shape of these rapidly moving bacteria appears to be oval rather than that of short rods. The explanation of these apparent discrepancies in both size and shape may be suggested by the facts that the organisms are being viewed when in very rapid vibration, which might make them appear larger than they really are, and this, together with the refraction of light as the result of what is probably a capsule, as demonstrated by Carpenter, may explain their apparent shape.

If sections from a slightly more mature part of the lesion are examined it will be seen that gum has begun to form and partly fill the xylem cells, while the part of the cell unoccupied by the gum may or may not be filled with motile bacteria. If this gum is examined carefully, bodies darker than the surrounding gum mass, closely approximating in size and shape the motile bacteria, are seen. In some cases these are seen to be in restricted motion, while in others no movement can be detected. Such sections were stained and are shown in Fig. 15 B.

In sections from a still more mature portion of a lesion, especially if the pink line has formed throughout its center, this gum mass extends across and completely fills the xylem cells. During this stage, as is shown in Figs. 15, C, D, F; 16, A, B, C, D, individual bacteria may be distinguished, but, usually, no motion could be seen. At this stage also the transverse bundle connection of both leaves and sheaths may be invaded by bacteria and occluded with the gum mass (Fig. 19, F).

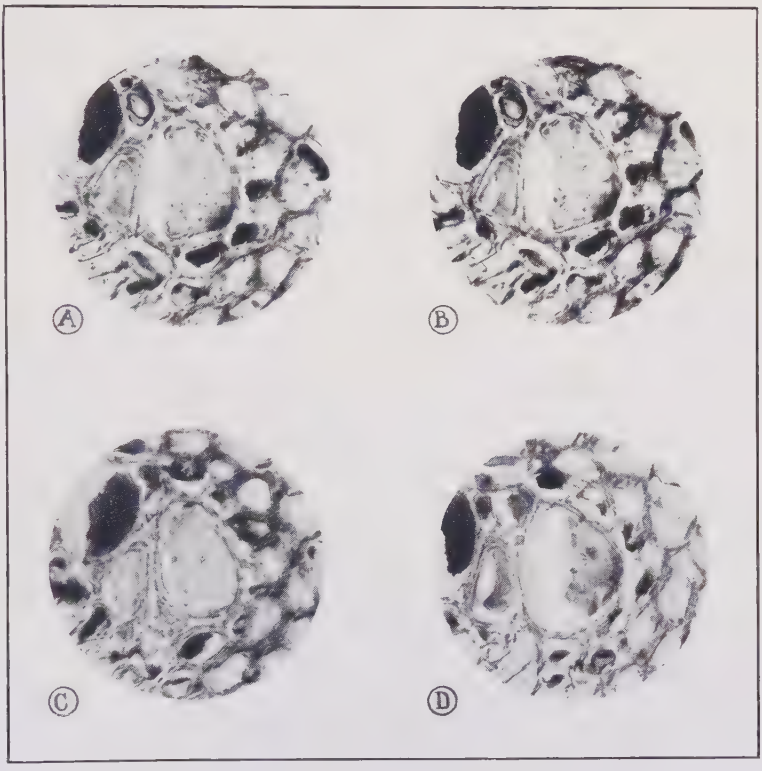


FIG. 16.

Transverse sections of bundles of a stalk of H 109 cane showing vessels occluded with gum-like masses containing bacteria (*Bacterium albilineans*). No external symptoms other than stunting were manifest by the plant from which these sections were made (X 534).

Characteristics of the Occluding Gum

As the lesion advances in age, the color of this gum changes from a light-brown through red-brown to a dark-brown color, photographing in different shades of gray to black, according to its age. Sometimes this color change takes place evenly throughout a given cell (Figs. 15, C, D, E, F, G; 20, C, F). At other times the dark color exists around the margin of the mass with a lighter area in the center (Figs. 15, I; 17; 18). Sometimes cells contain this dark marginal area while the central area is an open channel (Fig. 19, B, C), which suggests that under certain conditions the advancement of the disease may be arrested. Later, when the disease renews its advancement, this channel becomes filled with a freshly formed gum mass, which may explain the condition of the lighter central area surrounded by the darker margin.

The true nature of the gum which occludes the xylem cells is little understood. Wilbrink (*loc. cit.*) calls it "wound gum." Occasionally it gave a slight red reaction with phloroglucin, but this reaction was so slight and so erratic that it could hardly be interpreted to be a true wound gum (30, p. 157). As no swelling could be obtained by soaking it in water, it is doubtful whether it is a true gum at all. According to Smith (24, vol. III), Cobb states that the gum of the Australian gumming disease *(B. vascularum)* is not a true gum.

In another place Cobb (9) states:

> Lenses of high power show the gum to be swarming with microbes of the form known as bacilli. . . . Each microbe has about it a small amount of gummy matter, which is the product of its growth. The gum described as issuing from the sap vessels of the cane has, therefore, two component parts, namely, microbes and a viscous gummy matter. This gummy matter appears to be a new substance, and to it I have applied the name of vasculin.

In view of the possibility of the leaf scald organism possessing a capsule, the possibility of this gum being a built-up mass of the organisms themselves should be considered.

Cell Walls

Many times the middle lamellae of xylem cells occluded with gum appear to have been dissolved (Figs. 15, F; 17; 18). In some cases the entire cell wall has been dissolved (Figs. 15, I; 18).

Lysigenic Cavities

The dissolving action of the bacteria on the cell walls of the host tissues is more commonly found when the organism invades the air spaces, or the schizogenic cavities, called the lacunae, which develop normally just outside of the annular vessels of the bundles and form an internal "ventilating" system of the plant. The action of the bacteria on these air spaces enlarges them by dissolving the cells surrounding them, thus forming the lysigenic cavities (26, p. 98). These cavities in various stages of advancement can be seen in Figs. 14, 15 A, H, I; 17; 19, A, B, D, E, F; 20, A, B, D, F.

FIG. 17.

Transverse section of a bundle of one of the white lines of a leaf of a cane plant (Manoa 160) affected with leaf scald disease. The lacuna just above the annular vessel is discolored and beginning to be enlarged by the action of the invading bacteria to form the lysigenous cavity. The gum-like masses occluding the two adjacent vessels of metaxylem show dark (older) marginal areas with lighter (more recent) central areas. The middle lamella can be seen in the cell wall separating the two occluded vessels, which is beginning to break down as the result of bacterial action. The xylem cells lying below the annular vessel and the cells of two regions of the phloem are discolored (X 776).

Phloem

In the earlier stages of the disease infection is confined to the xylem cells, but, as the disease advances, apparently the infection invades the phloem (Figs. 14; 15, H, I; 17). This invasion does not affect the phloem evenly, as can be seen in the photomicrographs just referred to. At no time was it possible to distinguish individual bacteria in the phloem in either fresh or stained sections, which makes it uncertain as to whether it is the invasion of the actual bacteria themselves or the diffusion of their secretions that produces this effect. Apparently there is no phloem necrosis.

Other Tissues

Much the same that was said about the phloem can be said of several other tissues. Occasionally cells of the starch sheath were discolored (Figs. 14; 15, A, G). This was true also of the phloem fibers (Fig. 15, F). As with the cells of the phloem, bacteria were not seen in these discolored cells in either fresh or stained sections. The cells of the chlorophyll-bearing parenchyma lost their green color at a very early stage in the development of the lesions, the color fading soonest from the cells nearest the upper surface of the leaf. This agrees with Wilbrink (*loc. cit.*), who states that this accounts for the fact that the white lesions are plainer on the upper surface of the leaf than on the lower. In Hawaii, even the lesions appearing on the outer leaves of the spindle were already quite as bright on the one surface of the leaf as on the other and it was necessary to find a lesion on leaves farther toward the center of the spindle before any great difference could be detected.

In transverse sections through a lesion on a leaf, it was seen that in the region of the lesion the green color was absent not only from the cells of the chlorophyll-bearing parenchyma immediately surrounding the starch sheath but from the large parenchyma cells, which contain chloroplasts and lie outside of this tissue between the bundles, and from the starch sheath itself. This was not true of these same tissues in a region of the leaf immediately adjacent to the lesion which were characterized by their normal, green color. As one passes from these tissues of the lesion region to those of the normal region juxtaposed, this color change takes place within the very narrow limit of one or two bundles and explains clearly the appearance of the sharply defined margin of the lesions. This was true of the sheath in only a slightly less degree.

A depression, or groove, in the outer surface of the sheath was occasionally found running parallel with an occluded bundle. This depression was interpreted as an indication that infection of the underlying bundle took place before the tissues of the sheath were fully developed and prevented their normal expansion. North (21, p. 34) describes this same condition together with that of a split of the tissues lying between the infected bundle and the *inner* surface of the sheath (a further indication of the earliness of the infection). This latter condition was not found on the varieties studied in Hawaii.

While the infection of leaf scald disease is usually confined within the bundles, as manifested by the gum masses within the xylem cells of leaf, sheath, and stalk,

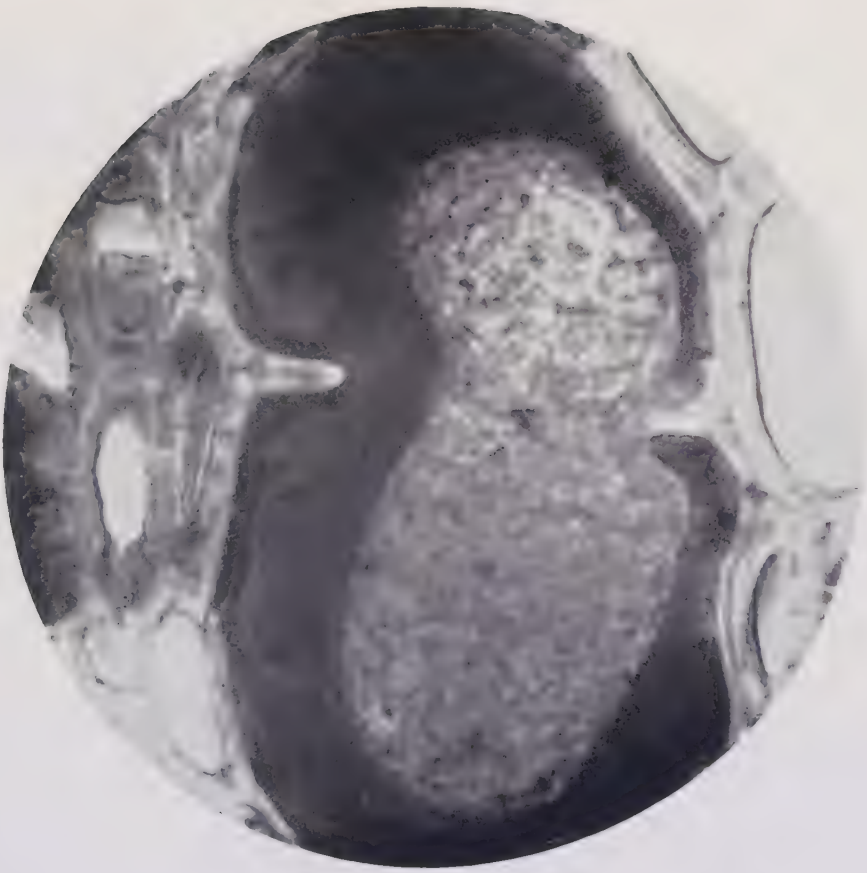


FIG. 18.
An enlarged view of the occluded vessel shown in Fig. 15, I (X 1747).

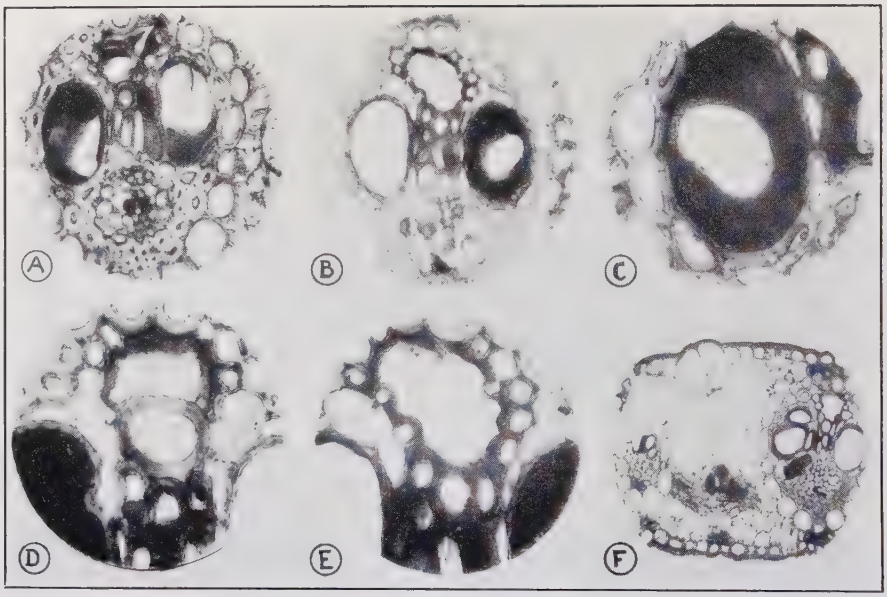


FIG. 19.

Transverse sections of bundles of leaves: A, showing vessels only partly occluded (X 238); B, showing a vessel with all but its central area occluded, and a well developed lysigenous cavity (X 238); C, an enlarged view of the occluded vessel shown in B, a condition frequently found (X 535); D and E, lysigenous cavities in different stages of advancement (X 535); F, showing occlusion of the transverse bundle connections (X 119).

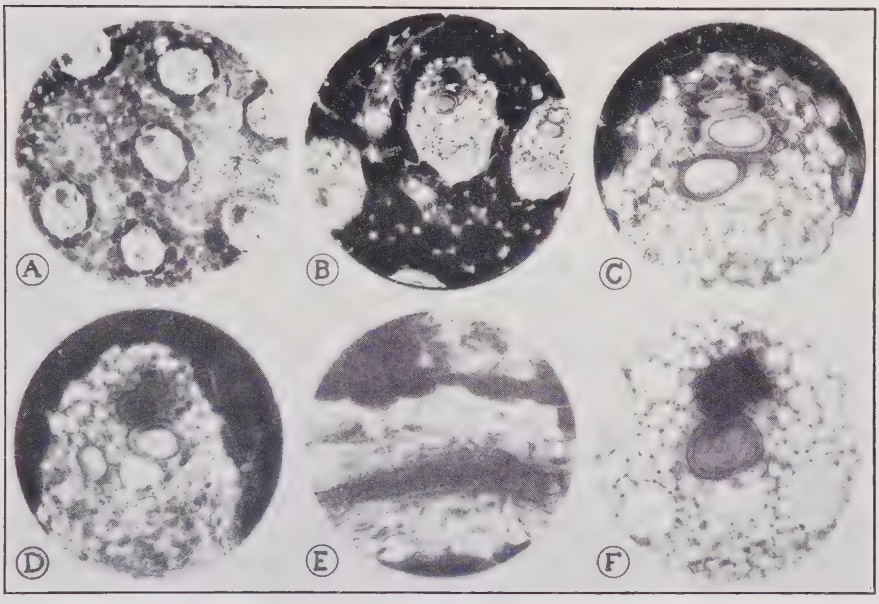


FIG. 20.

Transverse section through an affected cane stalk near the growing point, showing how the vessels of the bundles have become occluded with a gum-like substance very soon after they are differentiated and how the parenchyma cells lying between them have already become of a dark color; a longitudinal section of one of the bundles of the stem after it has changed the course from a perpendicular direction and just before it passes from the stem to the leaf sheath is shown in E. (X 238.)

this is not always the case, for, where the tissues are soft, just below the growing point, the disease invades the parenchyma tissue between the bundles, forming reddened pockets of gum. These pockets can be seen in the colored plate. When examined microscopically these pockets were seen to be composed of partially collapsed or dead parenchyma cells filled with a granular gum mass resembling in both texture and color that which occluded the xylem cells. Not only was it present within these cells, but filled the spaces between the cells as well. Occasionally cracks or cavities occurred, especially in the more advanced stages of the disease. In the gum masses no bacteria could be distinguished.

If stained sections taken from the region of the stem just below the growing point are examined, it will be seen that not only are the xylem cells of the newly differentiated bundles already occluded with gum, but the parenchyma cells lying between the bundles are affected as well (Fig. 20, A, B, C, D). In the newly differentiated bundles of the growing point, which lead to the leaf sheaths, these vessels also are already occluded (Fig. 20, E). In the newly formed vessels of the sheath the same thing is true (Fig. 20, F). It is apparent from these photomicrographs that the organism invades the xylem cells very soon after being differentiated in the growing point. In Fig. 20, F (as well as in others) this invasion is clearly illustrated. Here, three xylem cells lying in a row show the order of their differentiation. The lowest and youngest of these three and two others at about the same stage of differentiation, one to its right and one to its left, are as yet uninfected. The middle and upper cells of these three perpendicular cells have already been occluded, the uppermost and oldest showing evidence of having been invaded first.

VI. THE CAUSAL ORGANISM

Bacterium albilineans Ashby was readily isolated from the affected tissues of leaves, leaf sheaths, spindles and nodes of affected plants. The medium recommended by Wilbrink (*loc. cit.*) was found satisfactory for the isolation and cultivation of the bacterium. The agar medium was prepared according to the following modified formula:

Distilled water	1000	cc.
Peptone (Bacto)	5.	gms.
Potassium phosphate (Dibasic)	0.5	gms.
Magnesium sulphate	0.25	gms.
Agar	15.	gms.
Cane sugar	10.	gms.

The above listed ingredients, with the exception of the sugar, were placed in the hot distilled water and the whole steamed at 15 pounds for 15 minutes. The concoction was then filtered and 10 grams of cane sugar dissolved therein. The medium was adjusted to a final reaction of pH 7.0 to pH 7.5 and sterilized for 15 minutes at 15 pounds. For a liquid culture medium the same formula was used omitting the agar. Subsequent experience has indicated that pH 6.8 is more favorable for growth, at least for cultures in cultivation for some months.

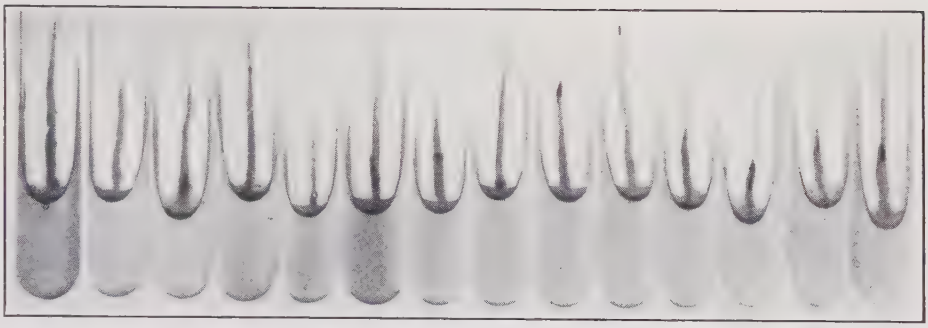


FIG. 21.

B. albilineans Ashby. Six-day-old sub-cultures on Wilbrink agar (X½).

From left to right: No. 438E (Manoa 160), Onomea, Hawaii; 439B (H-109), Waipahu, Oahu; 441W (2), 441W (4), 443, 443I, 445 (Manoa 160), Onomea, Hawaii; 446C (Wailuku 12), Koloa, Kauai; 447C (Manoa 160), reisolation of 439B; 448A (seedling Yellow Tip X 26-C-59), Hakalau, Hawaii; 451A and 451B, (26-C-182), reisolation of 439B; 452A and 452I (Wailuku 12), Quarantine House, Honolulu, reisolation of 439B. (Photo June, 1931.)

Isolation Technique: After surface disinfection of leaf and stalk tissues in alcohol and mercuric chloride solution, small portions were dissected out with flamed knives and planted in poured agar plates. A method yielding at once a high percentage of pure cultures has been described by Wilbrink, wherein the leaves of the spindle are aseptically dissected off, the tip of the rolled spindle leaves repeatedly being cut off with a flamed knife. The end of the inner rolled cylinder of leaves of the spindle, close to the growing point, is then repeatedly streaked on the surface of the several agar plates. The bacterial growth appears after one to two weeks, or later, as a beaded colony growth and series of parallel streaks of watery droplets, or pale yellow, glistening, somewhat raised, masses (Fig. 22). Gradually the color becomes deeper yellow. At first, by transmitted light the growth appears somewhat opalescent, later assuming a characteristic, peculiarly clear, amber, glassy appearance. By reflected light the yellow color very nearly resembles cream buff, Ridgeway (23; Plate XXX, Fig. 19D), becoming later, after three to four weeks, colonial buff (Fig. 21D) and finally deep colonial buff (Fig. 21B). Growth which starts from planted bits of leaf or stalk tissue may first be detected with the hand lens in one to three weeks, as a light colored, gradually increasing mass of bacteria. Under the low power of the microscope this growth is seen to be a finely granular colony with entire edge. The growth of *Bacterium albilineans* about such pieces of planted tissue was often extremely slow. Cultures were obtained also by forcibly inserting the flamed platinum needle into the vascular tissues of the cut end of the streaks of leaf sheaths and stroking the needle on the agar surface or inoculating tubes of agar for dilution plates.

The bacterium was isolated in pure culture many times by the spindle smear method and by aseptically planting bits of tissue of leaf and leaf sheath, as well as the red discolored tissues of the upper nodes of the stalk on agar plates. Reisolations also were made many times from plants diseased as a result of inoculation with *B. albilineans*.

Morphology. Neither Wilbrink nor North named the organism which they studied. The former reported no success in staining the flagella. A knowledge of the disposition of these appendages is necessary to determine the genus of a motile bacterium.

Ashby (2, pp. 137-138) examined a culture of the leaf scald bacterium furnished by North and his brief account of his observations follows:

> The writer has examined a culture kindly furnished by North and has found the bacterium actively motile in young cultures, by means of a single polar flagellum three to five times the length of the rod and has not observed it to liquefy gelatin. The binomial *Bacterium albilineans* is proposed for it on account of the long white leaf stripes of uniform width which are characteristic of the disease.

Ashby did not publish a photomicrograph of *Bacterium albilineans* in this paper, nor elsewhere, according to a review of the available literature.

Bacteria from young cultures on agar or liquid media, were stained by Carpenter, who used Loeffler's method to demonstrate flagellation. Characteristically the local bacterium has one polar flagellum as Ashby has reported for the leaf scald bacterium. This flagellum may be many times longer than reported by

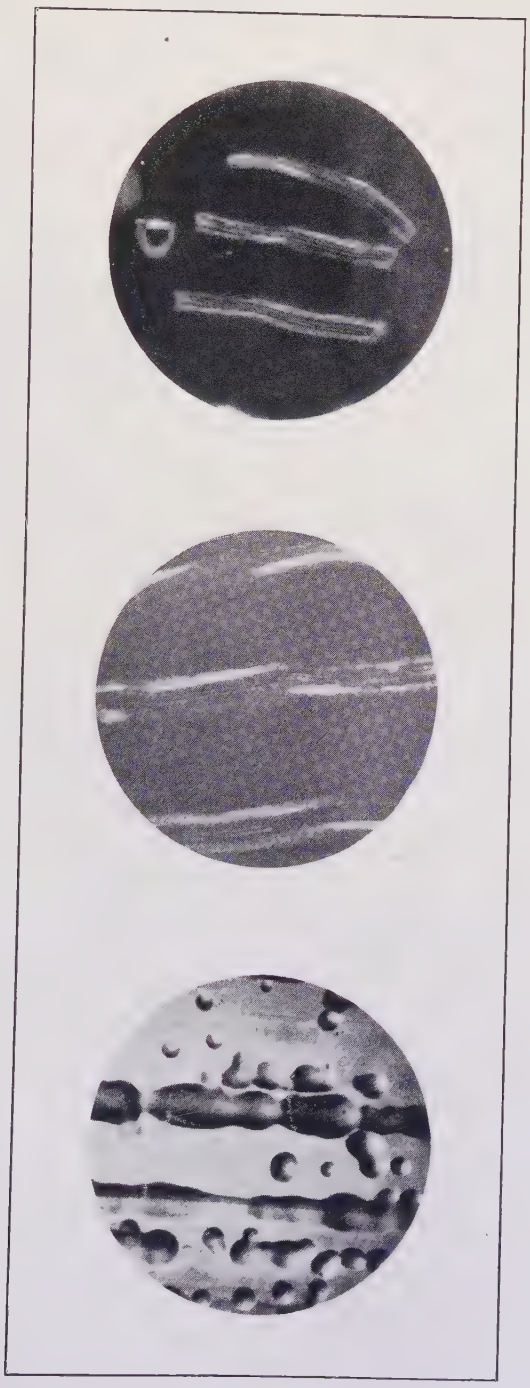


FIG. 22.

B. albilineans. Growth on Wilbrink agar. Spindle smears from Wailuku 12, ten days after inoculation with strain 439B (Yellow). From top to bottom: one-half natural size; portion natural size, and portion X 12, approximately. (March 17, 1931.)

Ashby. Some evidence of the presence of a capsule surrounding the bacterium has been noticed in the preparations made to demonstrate the arrangement of flagella, particularly where 11-day-old cultures on liquid media were used for the studies (Fig. 23 E, F).

The Loeffler formula used was that given by Smith (24, Vol. I, p. 190). Ziehl's carbol-fuchsin was used for staining 1 to 2 minutes after mordanting the dilute, dry, preparations for a similar period of time. Both mordant and stain were heated until steam arose during the process. Good preparations were comparatively difficult to obtain, especially preparations suitable for photographing, which showed single bacterial cells with a flagellum, rather than chains of two or more elements, or masses of many elements. Bacteria with flagella are shown in Fig. 23.

Studies of the characteristics of *Bacterium albilineans* in Hawaii have been confined to such observations as would serve for comparison with the descriptions of Wilbrink and North for the purpose of confirming the identification of the organism. Exhaustive studies have not been attempted with respect to the features mentioned below. The reader is referred to descriptions by Wilbrink and North for more detailed observations.

Table I shows a number of the salient features of *Bacterium albilineans* as found by Wilbrink (Java, *loc. cit.*), North (New South Wales, 21), and Carpenter (Hawaii). This table is followed by a number of pertinent observations reported by Wilbrink, since her paper may not be generally available to investigators of cane diseases. It is hoped that this combined data will prove sufficient for identification of *Bacterium albilineans* in the absence of a complete description by any one investigator. A study of the symptoms of cane where leaf scald disease is suspected, combined with brief studies of any vascular bacterium which may be isolated, should serve to complete the diagnosis.

The dense colonies of several common bacteria, more or less yellow in color, which frequently appear in plate cultures of cane material, should not be mistaken for the characteristically transparent colonies and smears of *B. albilineans*. The rate of growth should serve to eliminate most of the yellow bacteria from consideration, since growth of *B. albilineans* in first isolations rarely is evident to the naked eye in less than 7 days. There is very little chance that *B. albilineans* will be detected with the ordinary nutrient agar medium and if the disease is suspected in localities where it is not known to occur, the use of spindle smears on Wilbrink agar generally serves in 7 to 15 days to develop the characteristic yellowish, transparent growth of this bacterium if it is present. This bacterium, however, is erratic in behavior even on Wilbrink agar and repeated trials are recommended to insure heavy seeding before negative conclusions are reached. Bell and Cottrell-Dormer (4) describe an improved medium for the culture of this bacterium. They discuss this improved technique as follows:

> Since the medium evolved in this laboratory may be of considerable assistance in this connection we have deemed it advisable to summarize the work on this particular phase of leaf scald. . . .
>
> The improved germination following the addition of small amounts of sodium sulphite has had a practical application in enabling us to investigate the problem of toxic ions and

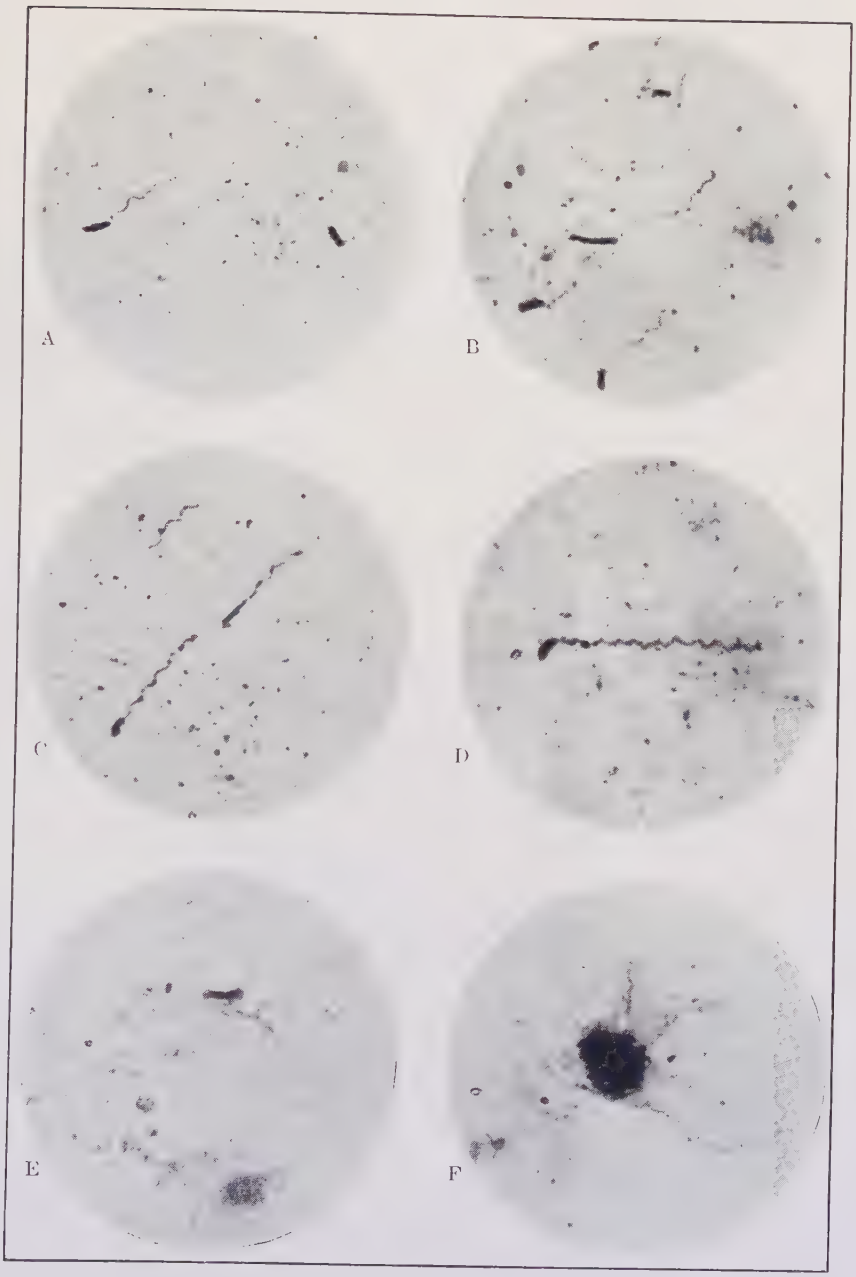


FIG. 23.

Bacterium albilineans Ashby. Flagella stained by Loeffler's method with carbol-fuchsin. A. X 1400 B-F. X 1800

In E and F there is an indication of a capsule; eleven-day culture in Wilbrink liquid medium. A to D from agar slant cultures.

is of decided value in enabling isolations to be made with greater rapidity and certainty. The following method of isolating *B. albilineans* from leaf tissue is therefore recommended: Prepare Wilbrink's agar according to the formula given above; dissolve 0.5 gm. of anhydrous sodium sulphite (or 1 gm. of sodium sulphite crystals)* in 9.5 ccs. of cool, freshly autoclaved distilled water, add 1 cc. of this solution to a further 9 ccs. of sterile distilled water; of this second solution add 1 cc. to each 100 ccs. of Wilbrink's medium. The sodium sulphite solution does not require sterilizing but freshly autoclaved water reduces the rate of deterioration. The solution is added before pouring. A portion of a leaf bearing a white pencil streak is well rubbed with alcohol, flamed, and a section of the streak cut out and macerated in a Petri dish in sterile water. The macerated tissue is allowed to soak for one hour, to permit of the bacteria diffusing out, and dilution plates are then made in the ordinary way. In the isolation illustrated on Plate I a pencil streak 2 inches long was macerated in 3 ccs. of water and 0.5 cc. of the suspension diluted to 10 ccs. which was again diluted 20 times; 0.5 cc. of inoculum per plate was used so that the inoculum used in inoculating the Petri dishes here depicted represents 1/1200 linear inch of a pencil streak.

This improved method has not been tried sufficiently in Hawaii to warrant comment on its merit for the cultivation of the local leaf scald bacterium.

Wilbrink (*loc. cit.*) contributed the following data on the bacterium which she investigated. Later evidence now indicates that this bacterium was *Bacterium albilineans* Ashby:

Strictly aerobic.

Sensitive to sunlight.

Sensitive to desiccation.

Secretes invertase.

Does not secrete diastase.

No coagulation, or visible surface growth on milk, though vigorous growth occurs.

No growth with ammonium salts, nitrates, or aspargin, as nitrogen sources. Requires more complicated compounds such as egg albumins or peptones.

Grows in presence of 1 per cent but not 2 per cent NaCl.

Carbohydrates. Poor growth in peptone water without carbohydrates. A fair growth in presence of glucose, saccharose, lactose or maltose. At first growth was difficult to establish with glucose; once started, growth was as good as with saccharose, occurring in the presence of 2½ and 5 per cent, but not 8 per cent glucose. With saccharose, growth slackened in the presence of 10 per cent.

Occurrence of B. albilineans in the cane plant:

The bacteria occur in the leaves, stalks and roots.

Occurrence outside of cane plant:

The bacteria could not be detected in the soil or in the water.

Viability of the bacteria in crusher juice:

Inoculations indicated that the bacteria, if still alive, had lost their ability to produce the disease after remaining 24 hours in the juice resulting from grinding diseased cane stalks.

VII. INOCULATION EXPERIMENTS

Inoculations with suspected cultures of *Bacterium albilineans,* on the island of Oahu, were made in strict isolation in a former quarantine house at the pathology plot, Honolulu, and were restricted to bacterial strains which originated on the island. These inoculations, made by Carpenter February 4, 1931, were

* .005% $Na_2 SO_3$ is found to be the optimum under the conditions of these experiments, and may be expected to vary with other samples of peptone for example.

TABLE I

COMPARATIVE CHARACTERIZATIONS OF *BACTERIUM ALBILINEANS* IN JAVA, AUSTRALIA AND HAWAII

	Wilbrink	North	Carpenter
Temperature Relation			
Optimum	27°–28° C.	25°–30° C.	About 25° C.
Maximum	36°–37° + C.	37° + C.	37.5° + C.
Minimum	.....	.....	.....
Thermal death point	52° C.	.....	.....
Relation to reaction of medium			
Opt. H-ion concentration. (Or reaction Fuller's Scale.)	(+ 20 (Fuller's scale)	(+ 25 (Fuller's scale)	pH 6.4–6.8.
Limits of pH for growth. (Or reaction Fuller's Scale.)	.....	(+ 10 to + 25 (F. S.)	pH 5.8–8.5 (Liquid media; Wilbrink formula.)
Growth on meat extract broth and peptone.	Grows freely.	Growth slight.	Very scant growth.
Surface	Cream colored skin.		
Clouding	Moderate to plentiful.		
Sediment	Fair amount of pale, yellow, flaky deposit.		
Amount			
Morphology			
Form	Short, slender rod.	Short, slender rod.	Short, slender rod.
Endospores	None.	None.	None observed.
Flagella	(Motile.)	(Motile.)	One polar.
Gram stain	Negative.	Negative.	Negative.
Chromogenesis	Honey yellow.	Buff yellow.	Cream buff (Ridgeway).
Vegetative cells, stained with carbol-fuchsin:			
Length	Nearly 1 micron.	1 micron.	.6 –1. micron.
Diameter	Slightly less than .5 micron.	.2 micron.	.25– .3 micron.
Chains and threads	Present.	Present.	Present.
Capsules	Not mentioned.	Not mentioned.	Apparently present.
Agar stroke. Growth Luster Surface	Colonies appear after one week with undulating edges. Naples yellow—clear to honey yellow or tea brown, moistly shining, edges entire.	Confluent to patchy, entire to very slightly spreading, raised. Glistening to dry, almost white, bluish-gray to yellowish.	Raised, entire, scattered colonies at edge. Glistening, buff to colonial buff, and by transmitted light, honey to buff yellow. Transparent. Peculiar glassy appearance. In age becomes translucent.
Agar colonies.	After 7 to 10 days minute transparent drops, becoming slightly arched discs, moistly shining. By reflected light are creamy white, by transmitted light, transparent honey yellow, to Naples yellow. No abundant slime formation observed.	After 7-16 days first growth evident. Tiny punctiform colonies appearing like droplets of oil or moisture on agar surface. Up to 2 mm. diameter frequently remain punctiform. Large colonies are round, smooth, convex, moist, glistening (more or less); opaque, bluish gray, nearly white by reflected light, translucent light buff yellow by transmitted light. Edges entire. Slightly spreading; soft cheesy consistency. Rarely slimy, thick and tenacious.	Not different in any feature mentioned by Wilbrink and North. Massed colonies by transmitted light have a characteristic yellow to amber, glassy appearance.

the first successful ones made with pure cultures of bacteria which proved to be *Bacterium albilineans* and the positive results obtained, combined with observations of the original strain, mentioned below as 439B, and reisolated strains, served to familiarize the writers with the bacterium, confirmed the diagnosis, and facilitated successful inoculations with the proper bacterium in the field.

The bacteria used were isolated from H 109 cane grown in Field 44, Oahu Sugar Company, Ltd. This small plot of cane had been grown from cuttings obtained in Field 83 at Onomea Sugar Company. Inspection of the cane December 19, 1930, at the instance of E. W. Greene, manager, had revealed minor symptoms of the leaf scald type of disease on two leaves of two separate stools. Portions of these affected stalks were wrapped carefully and removed to the laboratory culture room in Honolulu. When the stalks were cut open December 19, 1930, a slight reddening of the vascular bundles of the nodes was apparent. The tissues of the spindle and upper nodes were disinfected in alcohol followed by 1-1000 bichloride of mercury, and after rinsing in sterile water, were aseptically dissected. Portions were planted in agar medium (Wilbrink formula) to permit the development of any organisms present. (Isolation methods found successful are given in greater detail on page 180.)

The isolated bacteria were pure cultures of very slow-growing types. They were given laboratory numbers as follows:

439 A1	439 B (yellow)
439 A2	439 X (isolated by C. C. Barnum)
439 B	

Cane Material for Inoculation: Two flats of sterilized potting soil were planted with each of the following varieties: Manoa 160, Wailuku 12, 26 C 182 and P. O. J. 2714. The three former varieties were considered susceptible to the local disease, while the last mentioned variety was reported susceptible to leaf scald disease in Australia by C. G. Lennox, assistant geneticist. Rapid growth was insured by placing the flats on the warm benches in the seedling propagation house. On February 3, 1931, when the shoots were from ten to fourteen inches high, the flats were removed to Quarantine House No. 2, Honolulu.

Sterile water suspensions of the mentioned bacteria were prepared in small plugged flasks. Two shoots of each variety in each flat were first inoculated in the spindle just above the growing point with sterile water by means of a sterile hypodermic syringe. Then two or more shoots of each variety were similarly inoculated with each of the five strains of bacteria. The object of this experiment was to learn which strains of the five very similar slow-growing bacteria were capable of inducing symptoms of the disease.

On February 16, or after a twelve-day incubation period, several faint, narrow white lines were noted, extending upward and downward from the point of inoculation on the now unrolled leaves of one shoot of Manoa 160 inoculated with strain 439B (yellow). The other two plants of this variety inoculated with this strain showed similar lines February 18, 1931. On the latter date one shoot of Manoa 160 inoculated with 439X also showed definite white lines running down the leaves from the points of inoculation.

Both shoots of the variety 26 C 182 inoculated with the strain 439B (yellow) appeared pale in color February 18, and by February 26, white streaks were conspicuous on several leaves of both plants. Definite symptoms of leaf scald had developed within three weeks on both plants of the variety 26 C 182, which was inoculated February 4, 1931, with the strain 439X.

On February 27, 1931, no further evidence of pathogenicity of any of the used strains was in evidence, with the possible exception of the two shoots of the variety Wailuku 12 inoculated with the strain 439B (yellow), and one shoot inoculated with the strain 439X. One leaf of each of three shoots showed a broad chlorotic or yellow-brown streak running from a point on the midrib in the middle part of the leaf toward the leaf tip. The general wilt symptoms suggested the acute stage described by North.

The variety Wailuku 12 did not grow well in the house, the leaves tending to droop. This tendency was much more pronounced in the shoots inoculated with the strains 439B (yellow) and 439X, both of which had produced leaf scald disease symptoms on the other three varieties of cane. The inoculated shoots of Wailuku 12 later developed a general chlorotic condition, most evident on the lower leaves. A broad, effuse, chlorotic streak was apparent on one or more leaves of each inoculated plant. There was a general wilt reaction combined with a lack of vigor rather than the leaf striping symptoms typical of leaf scald. This condition which did not occur in the controls inoculated with sterile water, nor in those plants inoculated with other strains of bacteria was interpreted as the acute stage of leaf scald.

The bacteria were reisolated March 6, 1931, from the spindle, growing point tissue and nodes, from such a diseased shoot of Wailuku 12 which had been inoculated February 4. Red vascular bundles were conspicuous in the small stalk when the material was prepared for culturing. Bacterial cultures, considered to be *Bacterium albilineans*, were isolated both from spindle and nodes (Cultures 452A, 452 I, Fig. 21).

The variety P. O. J. 2714 showed inconspicuous leaf stripes following inoculation with strain 439X. This variety appeared the least susceptible of the four varieties in the first experiment. The leaf symptoms were slow in appearing and not as clearly defined.

Two flats were planted with cuttings of the variety H 109, January 5, 1931. On February 28 ten shoots of this variety were inoculated hypodermically in the spindle with liquid cultures of strain 439B (yellow). Sterile nutrient medium was used for five controls. On March 17 definite narrow white lines were evident extending upward and downward from the punctures in the new leaves, a few days having elapsed since they unrolled from the spindle. Four days later nine of the ten inoculated shoots had developed clear-cut white lines on one or more of the new leaves, directly associated with the needle punctures.

None of the controls of any variety nor shoots inoculated with bacteria which formed no yellow pigment showed the slightest evidence of white streaks comparable to those produced by the two strains cited.

One shoot of Manoa 160, which had been inoculated with the strain 439B (yellow) was removed from the seed piece February 27, 1931, and taken to the

culture room. Dissection of the small shoot showed that some of the vascular bundles of the nodes close to the growing point were reddened. The bacteria used for inoculation were reisolated, sixteen pure cultures having been isolated from various parts of the smears, or planted bits of tissue.

It might be stated that the conduct of this quarantine house was personnally supervised by Martin and Carpenter and no one had access thereto unaccompanied. Cane material was invariably placed in a tin container and sealed before removal from the house for study. The container was washed in creolin solution and taken to the culture room at the pathological laboratory.

Additional inoculations were made March 7, 1931, in the quarantine house, using other shoots in the same flats, and also a number of ratoon shoots in pots of Manoa 160. The results were the same; practically every shoot inoculated with the strain 439B (yellow) in the several series developed the white leaf streak symptoms in greater or lesser degree within three weeks. The symptoms recurred on the new uninjured leaves subsequently developed by such shoots. Inoculations by needle pricking of expanded leaves of all the used varieties were made, but in no case did the symptoms follow.

These inoculations established the fact that typical leaf scald symptoms could be produced by injecting the spindles with slow-growing bacteria which form a characteristic yellow pigment on the agar medium and morphologically resembled *Bacterium albilineans* as described by Wilbrink, North and Ashby. One similar strain, No. 445A, isolated from the variety Manoa 160 from Onomea, had been already demonstrated to be motile by means of a single polar flagellum.

Seven strains of this type isolated by Carpenter from Manoa 160 collected at Onomea were therefore taken to Onomea Sugar Company, on Hawaii, February 20, 1931, for inoculation purposes. These were strains numbers 438E, 441W (2), 441W (4), 443, 443 I, 445 and 445A (Fig. 21), all of which proved to be parasitic, as recorded in Table II. Other similar strains used at this time for inoculations at Onomea were Nos. 14 and 15, isolated by Martin. The control plants inoculated with sterile water and broth remained healthy.

Nine pure cultures of bacteria resembling those of *B. albilineans* were isolated by Weller, who conducted an inoculation experiment with them at Koloa Sugar Company on Kauai. Healthy plants of the varieties Manoa 185 and 186 were used. A series of direct inoculations was also carried out, by inoculating healthy plants with a hypodermic needle near the growing point with an infusion prepared by macerating diseased tissue in sterilized distilled water. Ten healthy plants were inoculated with each of the nine cultures and a like number used for the direct inoculations. From 70 to 100 per cent of the several series of plants inoculated developed definite symptoms of leaf scald disease (Fig. 7). Ten healthy plants which were inoculated with Wilbrink's broth served as controls. These remained healthy throughout the tests. Detailed results of these experiments are included in Table II.

TABLE II

RESULTS OF FIELD INOCULATIONS

ISLAND OF HAWAII

Variety—Manoa 160
Inoculations made February 20, 1931
Final observations recorded April 22, 1931

Stalk Number	Distilled water	Wilbrink's broth	Direct inoculations*	Culture No. 14	Culture No. 15	Culture No. 438E	Culture No. 441W(2)	Culture No. 441W(4)	Culture No. 443	Culture No. 443-1	Culture No. 445	Culture No. 445A
1	—	—	+	+	+	+	+	—†	—†	+	+	+
2	—	—	+	+	+	—†	+	+	+	+	—?	+
3	—	—	+	+	+	+	—	+	+	+	+	+
4	—	—	+	+	+	+	—	+	+	+	+†	+
5	—	—	+	+	+	+	+	+	+	—	+	+
6	—	—	+	+	+	+	+	+	—†	—	+	+†
7	—	—	+	+	+	+	—	+	+	+	+	—
8	—	—	+	+	+	+	+	+	+	—	+	+
9	—	—	+	+	+	+	+	+	+	+	+	—
10	—	—		+	—	+	+	+	—†	+	—	+
Number positive	0	0	9	10	9	9	7	9	7	7	8	8
Per Cent Positive	0	0	100	100	90	90	70	90	70	70	80	80

ISLAND OF KAUAI

Varieties- Manoa 185 and 186
Inoculations made March 24-26, 1931
Final observations recorded May 29, 1931

Stalk Number	Wilbrink's broth	Direct Inoculations	Culture C	Culture D	Culture E	Culture F	Culture H	Culture I	Culture J	Culture K	Culture N
1	—	—	+	+	+	—	+	+	+	+	+
2	—	—	+	+	+	+	—	+	+	+	+
3	—	—	+	+	+	+	+	+	+	+	+
4	—	—	+	+	+	+	+	+	+	+	+
5	—	—	+	+	—	+	+	+	+	+	+
6	—	—	+	+	—	+	+	—	+	+	+
7	—	—	+	+	+	+	+	+	+	+	+
8	—	—	+	+	+	+	—	+	+	+	+
9	—	—	+	+	—	+	+	+	—	—	+	+
10	—	—	+	+	+	+	+	+	+	—	—
Number positive	0	7	10	8	9	9	7	9	9	10	9
Per Cent Positive	0	70	100	80	90	90	70	90	90	100	90

* Inoculations made December 22, 1930, with an infusion prepared by macerating diseased tissue. Final observations recorded February 20, 1931.
† Pokkah boeng symptoms or dead spindle.
Culture E—One acute stage.

VIII. VARIETIES AFFECTED

As already mentioned, the presence of leaf scald disease was first established in the early part of 1931 as occurring on the cane varieties Manoa 160, H 109, 1926 C 182 and Wailuku 12. Since that time the disease has been found on sixteen other cane varieties, namely:

Manoa 31, 96, 160, 185, 186 and 195.
Yellow Tip.
Striped Tip.
H 335.
Kohala 73, 107 and 202.
1926 C 187.
1927 C 350.
U. D. 1.

Of these varieties, Yellow Tip, Striped Tip, Manoa 160, 185, 186 and 195 and Kohala 107 and 202, have proved to be the most susceptible. On the others the disease is thus far sporadic. In certain instances, the symptoms appearing on several of the above-named varieties were atypical, for example, on the variety Kohala 202 at Hakalau. In such cases *B. albilineans* was isolated and identified before a positive diagnosis was completed.

With the exception of H 109, U. D. 1, Yellow Tip, Striped Tip and Kohala 107 the remaining cane varieties listed above are still in experimental tests regarding their merits as commercial cane varieties. At present both Yellow Tip and Striped Tip canes are being rapidly replaced by canes of superior agricultural qualities which incidentally are much more resistant to leaf scald disease. The disease has not been observed on the following commercial varieties: Yellow Caledonia, D 1135, P. O. J. 36, 213, 2878 and Badila.

The disease has been observed in two instances on H 109 cane, the variety most widely grown on the irrigated plantations. Two affected stools at Oahu Sugar Company, Ltd., on the island of Oahu, and a test plot at Onomea Sugar Company, on the island of Hawaii. In the former case cuttings of H 109, obtained from the latter plot at Onomea, were planted. The plot of H 109 cane at Oahu Sugar Company, Ltd., wherein two leaf scald diseased stools were found, together with a certain amount of adjoining cane of the same variety and of H 456 was immediately destroyed by the management. The area in which the H 109 cane was destroyed was left fallow for five months and then planted to the susceptible variety Manoa 160. The object of planting this variety was to determine if, perchance, as a result of soil infection, the disease might develop. Monthly inspections were made of this area of Manoa 160 and during ten months no symptoms of leaf scald disease were noted. There is reason to believe that the disease was completely eradicated and does not now exist on the island of Oahu.

No systematic experimental tests of the commercial and more promising new varieties have been conducted to determine the degree of susceptibility. Such tests are being considered in order that information may be available should the disease become epidemic.

As a result of field observations and experimental tests Wilbrink (*loc. cit.*) has listed a number of the Java cane varieties in relation to their sensitiveness to the disease as follows:

Very Sensitive	Sensitive	Slightly Sensitive
E. K. 2	E. K. 28	Fiji
Brown 100	D. I. 52	P. K. I.
Black Borneo	S. W. 3	B. 247
Yellow Batjan	P. O. J. 826	Kassoer
B. 221	F. 90	
B. 36	Tjepiring 24	
P. O. J. 312	Black Cheribon	
P. O. J. 979	Chunnee	
P. O. J. 100	Loethers	

North (*22*, p. 15) published a list of a number of the Australian cane varieties in which they are arranged in order of their degree of susceptibility to leaf scald, as follows:

Susceptible	Moderately Resistant	Susceptible but Tolerant	Highly Resistant
Mahona	Nanemo	Badila	Malabar
H. Q. 243	Oramboo		N. G. 14
7. R. 96	Korpi		Innes 131
8. R. 31	(Clark's Seedling H. Q. 426)		D 1135
H. Q. 114	Pompey (7. R. 428)		H 109
	Goru and Sports		H. Q. 5
	(N. G. 24, 24A, 24B)		H. Q. 409
	N. G. 16		Q. 813
	M. 1900 Seedling		

Shepherd (*25*) during a recent visit to Australia and Java commented on the degree of resistance of certain varieties to gumming disease and leaf scald disease in these two countries. Shepherd comments as follows on the behavior of certain varieties in relation to leaf scald:

White Tanna (known as Malabar in Australia)—Moderately susceptible and tolerant to leaf scald, apparently more so than it is in Mauritius. . . . .

Black Innes apparently identical with M. 131—seems immune to leaf scald.

R. P. 6—Very resistant to "scald."

D. 1135—Highly resistant to "scald."

P. O. J. 2878—Moderately susceptible to "scald." Degree of susceptibility warranting the application of control measures in Java. . . . . .

B. H. 10/12—Apparently reacts to "scald."

Badila—Moderately susceptible but highly tolerant to "scald." It seems to possess a higher degree of tolerance to the disease than does White Tanna. Under the tropical conditions of Northern Queensland its tolerance seems less than in the subtropical districts of Northern New South Wales.

P. O. J. 2714—No information is available as to its behavior to "scald."

S. C. 12/4—No information is available as to its behavior to "scald."

Q. 813—It is highly resistant to "scald" and other diseases, in addition to gumming.

The following list of commercial cane varieties grown in Queensland has been prepared by Bell. The varieties are segregated according to their resistance to the disease:

Highly Resistant	Resistant	Moderately Susceptible	Susceptible But Tolerant	Susceptible	Very Susceptible
D 1135	M. 1900	P. O. J. 2878	Badila	H. Q. 426	E. K. 28
M 189 (Black Innes)	H 109	P. O. J. 2714	S. J. 4	Goru	
Uba		Pompey			
Q. 813		Oramboo			
H. Q. 409		Nanemo			
		Korpi			

IX. ECONOMIC IMPORTANCE

North (21) points out that the greatest economic losses in Australia were in connection with the variety Mahona, which proved extremely susceptible to leaf scald. In several districts the culture of Mahona, a very high sucrose cane, had to be abandoned.

The greatest losses occur from attacks of leaf scald disease when entire stools are killed outright. There is not only a reduction in cane and sugar yields but additional costs are incurred in replanting the blank spaces should the epidemic be sufficiently severe to kill out large numbers of stools. The degree of infection and severity of the disease depends upon the susceptibility of the cane variety grown and in some measure on the climatic conditions.

According to Bell, definite losses in Queensland have occurred on Badila cane under somewhat unfavorable growing conditions, but the major losses in recent years have occurred in H. Q. 426, which is an early maturing variety. So far a suitable variety has not been found to replace H. Q. 426. Several very promising commercial seedlings, such as S. J. 7 (South Johnstone), proved susceptible to leaf scald and were discarded. In Java, Wilbrink stated that the disease often causes severe damage in young plant fields and that it was not possible to grow certain varieties having high sugar-yielding qualities because of their susceptibility to the disease. She also pointed out that the sugar yields have been reduced in those fields where the disease was epidemic. The losses in Formosa from the disease in the commercial fields have been negligible, according to Miyake. Economic losses in other sugar-growing countries have been somewhat severe on susceptible varieties.

In Hawaii no commercial losses have resulted from the disease since it has been found in such limited areas. It has been recommended that very susceptible varieties, such as Manoa 160, 185, etc., be eliminated at the end of the crop cycle. Leaf scald is potentially of considerable economic importance and it is advisable that susceptible cane varieties be avoided unless their commercial superiority warrants the care necessary to prevent the development of the disease in large areas.

X. TRANSMISSION

Leaf scald, being a systemic disease, is transmitted chiefly by planting diseased cuttings and by knife infection. The transmission of the disease by cut-

tings has been repeatedly demonstrated in controlled experiments in Java and Australia. The occurrence of the disease in certain fields has been definitely associated with cuttings taken from affected fields. There are several authentic records showing that the disease has been carried from one country to another with cane cuttings. Bell and Cottrell-Dormer (4, p. 1) state:

> Owing to the masking of symptoms under certain conditions, leaf scald is very difficult to detect, even in very susceptible varieties, and for this reason we expect that it will soon be found to have penetrated the quarantine defences of most countries. Moreover, one may very commonly find leaf markings which are very similar to those associated with leaf scald, but not positively identifiable except by recourse to cultural methods. To ensure reliable conclusions as to the presence or absence of the disease under these conditions it is obvious that there should be no doubt as to the suitability of the culture medium employed for isolation purposes, irrespective of heavy or light seeding.

North (22, pp. 30, 31) comments on the transmission of the disease as follows:

> Use of Infected Planting Material.—This has undoubtedly been the chief means of dissemination. There can be little doubt that the disease was first brought to Australia and was then distributed far and wide in infected cuttings. That it was introduced to the Richmond from the Clarence in 1912 in cuttings of N. G. 16 is known. Growers have also propagated the disease on a large scale by using cuttings from infected fields for planting. Even those who are familiar with the disease are still propagating it in this manner, because it is impossible to select only healthy seed cane from an infected crop, even from a very slightly infected one. For many canes which are infected are of normal healthy appearance and devoid of any symptoms which betray their condition. And cuttings from these produce diseased stools of cane.

Both North (22) and Wilbrink (*loc. cit.*) have shown that the causal organism of leaf scald disease may easily be transmitted with cane knives. Cane cuttings for planting material were prepared from healthy stalks with a sterilized knife. These cuttings produced healthy plants. Cuttings were prepared also from healthy stalks of cane but were cut with a knife contaminated by cutting affected stalks. In almost every case the young shoots resulting from these cuttings manifested definite symptoms of leaf scald disease. The results of such a field test, conducted by Wilbrink, are shown in Fig. 13.

The subject of knife infection has been summarized by North (22, p. 40) and a portion of his summary follows:

> In view of the wide use made of cane knives in ordinary farm practice, it seemed that knife infection might be one of the chief modes of dissemination. In harvesting crops for the factory, it would serve to transmit the disease from stool to stool in fields to be ratooned. The cane cutters might also carry infection on their knives from one field to another. In harvesting seed cane and preparing cuttings for planting, not only would the ratoon crops be concerned, but the fields newly planted would be still more vitally affected. The seed cane would be liable to knife infection both while being harvested and while being cut up into cuttings.

Wilbrink recommends a 5 per cent solution of lysol in preference to mercuric bichloride (1-1000) for disinfection. The latter attacks the metal in the knives. It is also considered advisable in Java to add a red or blue color to the lysol solu-

tion so that the inspectors can easily see if the men who are preparing the cuttings are properly following instructions. Following this procedure the cut ends show red or blue stains when examined.

In Australia it has been suspected that the disease is also transmitted by means other than those above mentioned. These methods are now being studied, but at present no definite information is available.

The possibility of the organism being able to remain viable in the soil for any period of time has been investigated. From studies of this particular point it appears that there is little danger of the organism persisting in the soil and later infecting cane plants. If susceptible varieties are planted subsequent to the plowing of an area where the disease has occurred, experience indicates that the varieties will remain healthy. Infection might occur as a result of diseased volunteer stools developed from the old stubble. Therefore, should it be necessary to eliminate a variety on account of leaf scald infection, every effort should be made to destroy ratoons before replanting. All attempts to transmit the disease through the soil have been negative. Apparently *B. albilineans* is poorly adapted to a saprophytic mode of life and is incapable of persisting long in the absence of a susceptible host plant. No references to alternate hosts have been found in the literature.

XI. CONTROL MEASURES

The outstanding recommendations for the control of leaf scald disease are those prescribed by Wilbrink, North and Bell. A summary of the recommended procedures follows in the order of their importance:

1. The substitution of resistant varieties is no doubt the most effective method for controlling the disease under epidemic conditions. According to North no variety has been found immune to the disease but many have shown a high degree of resistance. He mentioned that the variety Mahona in Australia proved so susceptible to leaf scald that it was necessary to abandon its culture in many districts, even though it was a very satisfactory commercial cane. For information regarding the relative susceptibility of varieties see pages 189-191.

In Hawaii, the Tip canes and some of the Manoa seedlings, namely, Manoa 160, 185, 186 and 195 appear to be highly susceptible to the disease when compared with many of the other varieties growing under identical field conditions. P. O. J. 36, which is replacing the Tip canes in certain localities, has proved to be quite resistant to the disease.

2. The selection of healthy cuttings for planting material offers an excellent measure for reducing the spread of leaf scald. The disease is systemic and is chiefly transmitted with diseased cuttings. By making frequent inspections of a field it is possible to establish whether or not it is advisable to select planting material therefrom when the field is harvested. In Australia, it is recommended that no cuttings be selected within a radius of a quarter of a mile of a diseased stool.

3. The disinfection of cane knives has aided in reducing the spread of the disease. Both North and Wilbrink have demonstrated that leaf scald disease may be transmitted with the cane knife. (See page 192 and Fig. 13.) Healthy cuttings were cut with knives that were previously used for cutting diseased stalks, and a high percentage of the plants from these cuttings developed the disease. Plants from healthy cuttings which were cut with sterilized knives remained healthy.

4. All diseased plants should be rogued and destroyed as soon as they are observed in the field. The disease has been successfully controlled by this measure in several countries, especially in localities where attempts to control the disease have been made before it became too widespread.

5. To insure healthy planting material for fields, or experimental tests, nurseries are sometimes maintained in isolated districts. By frequent inspections and roguing diseased plants, the "seed" plots are kept free from the disease. By this practice it is possible to begin with entirely healthy planting material.

6. Another measure of control that offers considerable promise is to subject cuttings to the hot water treatment if there is any question regarding their condition. The cuttings are submerged in water at 52° C., for 20 minutes. Following this treatment they are immediately placed in cold water in order to quickly lower their temperature. It will be necessary to conduct further tests with our different varieties before the effectiveness of this treatment under local conditions can be determined.

XII. SUMMARY

Leaf scald disease of sugar cane was first recognized in the Hawaiian Islands in December, 1930, although there is evidence which indicates that this disease has been present sporadically for many years. The history of this disease in other countries shows that it is capable of causing serious economic losses where large areas of susceptible cane varieties have become infected.

The cause of leaf scald disease is a minute bacterium about 0.3 x 0.8 micron in size, named *Bacterium albilineans* Ashby. This bacterium was isolated, cultivated and identified many times in the course of these studies. Its relation to the disease was proved by inoculations of cane grown under carefully controlled conditions as well as in the field.

The characteristic symptoms of this disease, if present in their entirety, are amply sufficient for diagnosis. However, it is insidious in nature and according to authorities is capable of existing in masked form for protracted periods. Two phases of leaf scald are recognized: (a) The chronic phase, characterized by white leaf stripes, the copious development of etiolated "lalas" (side shoots) and suckers, and red discolorations of the vascular bundles in the nodes; (b) the acute phase with less definite symptoms, which terminates in sudden wilt of individual stalks, stools or entire fields.

The bacterial infection is transmitted chiefly by diseased cane cuttings and by cane knives. The latter, becoming infected in cutting a diseased stalk may infect

propagating material, or the stubble of cane being cut for seed. There is no evidence indicating that infection persists for long periods in the soil.

Procedures recommended for the control of leaf scald in Australia and Java emphasize the importance of sanitary precautions. Cuttings from healthy cane only are considered for planting and transmission by knife infection is prevented by the use of disinfecting solutions. Regarding the choice of cuttings for planting, experience in Australia has indicated that no cuttings should be taken from cane within one-half mile of any leaf scald diseased stool.

In Hawaii, leaf scald disease has thus far been almost entirely restricted to a few areas of locally bred varieties, on the islands of Hawaii and Kauai, with a limited sporadic occurrence elsewhere. No appreciable commercial loss has been experienced. However, the disease should be regarded as potentially important to our industry, since the outcome of exposing our fields of present and future commercial varieties to infection cannot be predicted with assurance. H 109 is reported to be susceptible to leaf scald in the Philippines and resistant in Australia, which might be construed to indicate inherent susceptibility of this variety, varying in degree with the climate. While the sporadic occurrence of this disease in Hawaii for a number of years indicates it to be a factor of minor commercial importance it may indicate a lack of opportunity to become epidemic.

In conclusion the authors wish to express their sincere thanks to the managers and other members of the personnel of the plantations and to members of the Experiment Station staff for the active cooperation extended to them during the progress of these studies.

LITERATURE CITED

1. Allen, Ezra. 1916. Studies on cell division in the albino rat (*Mus Norvegicus*, var. alba). The Anatomical Record, Vol. 10, p. 570.
2. Ashby, S. F. 1929. Gumming disease of sugar cane. Tropical Agriculture, Vol. VI, pp. 135-138.
3. Bell, A. F. 1929. A Key for the Field Identification of Sugar Cane Diseases. Division of Pathology, Bureau of Sugar Experiment Stations, Queensland, Bulletin No. 2, p. 20.
4. Bell, A. F., and Cottrell-Dormer, W. 1932. An improved method for the isolation of the leaf scald organism. A paper presented at the Fourth Congress of the International Society of Sugar Cane Technologists, at Porto Rico, March, 1932.
5. Chamberlain, Charles J. 1924. Methods in Plant Histology. Fourth Revised Edition, p. 21.
6. Christopher, W. N., and Edgerton, C. W. 1930. Bacterial Stripe Diseases of Sugar Cane in Louisiana. Journal of Agricultural Research, Vol. XLI, p. 259.
7. Cobb, N. A. 1893. Gumming of Cane. Reports of Dept. of Agric., N. S. W., pp. 8-10.
8. ———— 1895. The Cause of Gumming in Sugar Cane. Agric. Gazette of N. S. W., Sydney, Vol. VI, pp. 683-689.
9. ———— 1905. Third Report on Gumming of the Sugar Cane. Experiment Station, H. S. P. A., Division of Path. and Phys., Bull. No. 3.
10. Dufrenoy, J. 1928. Staining Cell Constituents in Diseased Plant Tissues. Stain Technology, Vol. III, p. 57.
11. ———— 1929. Double staining of Mitochondria and Bacteria in Plant Tissues. Stain Technology, Vol. IV, p. 13.

12. Groenewege, J. 1915. De gomziekte van het suikerriet, veroorzaakt door *Bacterium vasculorum* Cobb. Archief Suikerindus. Ned. Indie, Vol. XXIII, pp. 189-284.
13. ———— 1917. De gomziekte van het suikerriet en hare bestrijding. Archief Suikerindus. Ned. Indie, Vol. XXV, pp. 597-638.
14. Lee, H. A. 1921. Observations on previously unreported or noteworthy plant diseases in the Philippines. Philippine Agricultural Review, Vol. XIV, p. 432.
15. ———— 1923. Gum diseases of sugar cane in the Philippines. Phytopath., Vol. XIII, p. 504.
16. Lee, A. Bolles. 1928. Microtomist's Vade-Mecum, Ninth Edition, p. 63.
17. Lyon, H. L. 1921. Three Major Cane Diseases: Mosaic, Sereh and Fiji Disease. Bulletin of the Experiment Station, H. S. P. A., Vol. 3, Bot. Series, Part 1.
18. McClung, C. E. 1929. Handbook of Microscopical Technique.
19. North, D. S. 1923. The control of sugar cane diseases. Agric. Rept. No. 6, C. S. R. Co., Ltd., Sydney, N. S. W. (Also in Australian Sugar Journal, March, April, May, 1923.)
20. ———— and Lee, H. A. 1924. Java gum disease of sugar cane identical to leaf scald of Australia. Phytopath. XIV, p. 587.
21. North, D. S. 1926. Leaf scald a bacterial disease of sugar cane. C. S. R. Co., Ltd., Agric. Rept. No. 8, Sydney, N. S. W.
22. — ———— 1929. Leaf scald disease of sugar cane and its control. (Condensed version.) C. S. R. Co., Ltd., Agric. Rept. No. 9.
23. Ridgeway, Robert. 1912. Color Standards and Nomenclature.
24. Smith, Erwin F. 1905. Bacteria in Relation to Plant Diseases. Vol. I, p. 190; Vol. III, p. 53.
25. Shepherd, E. F. S. 1931. Report on visit to Australia and Java. (Mauritius report.)
26. Strasburger, E. 1908. A Text Book of Botany. Third English Edition.
27. Tempany, H. 1928. Agriculture in Mauritius. Tropical Agriculture V, p. 227.
28. ———— 1928. Annual Report of the Department of Agriculture (Botanist) for the year 1928, Colony of Mauritius, pp. 10-11.
29. Wilbrink, G. 1920. De gomziekte van het Suikerriet, hare Oorzaak en hare Bestrijding. Archief Suikerindus. Ned. Indie, XXVIII, pp. 1399-1525.
30. Zimmerman, A. 1901. Botanical Microtechnique, p. 157.

A Study of Correlation Between the Cane Yields and Quality Ratio of Irrigated Cane

By Ralph J. Borden

General opinion prevails amongst our sugar men that poor juices are ordinarily associated with high cane yields, and conversely that with lower cane yields, we are apt to have better juices. We have, however, noted numerous exceptions to this generalization and have seen excellent juices from high cane yields as well as very poor juices from yields that were less than average ones.

The relationship of these two factors has been studied by subjecting the individual plot data from all field experiments that have been conducted at Waialua Agricultural Company and the Waipio substation on the crops from 1926 to 1931, inclusive, to a correlation study. The results which are offered in the accompanying table may be best interpreted in conjunction with the following table which has been adapted from Fisher and shows the amount of correlation (r) which is needed for significance when different numbers of items are being compared.

Actual No. of Items	Amount of Correlation (r) Needed for Significance	Actual No. of Items	Amount of Correlation (r) Needed for Significance
3	.997	11	.60
4	.95	12	.58
5	.88	13	.55
6	.81	14	.53
7	.75	15	.51
8	.71	18	.47
9	.67	20	.40
10	.63	44	.29
		100	.19

The tests have been segregated into similar groups, i.e., Amounts of Nitrogen, Amounts of Phosphate, etc., and the correlations for each treatment are tabulated thereafter. A total of 74 experiments is included, in which 227 correlations have been made. Only 36 of these show a correlation coefficient that is large enough to be considered definitely significant, and of these, 31 are significantly negative and 5 significantly positive. There is no question but that the predominance of negative signs in the column of r, indicates that the aforementioned opinion, which associates high yields with poor juices and lower yields with good juices, may be right. The fact, however, that fully one-third of the cases studied show positive signs, is also an indication that good juices may accompany the higher yields, or poor juices the low yields. Most of us know of instances of positive correlation between poor juices and low tonnage, particularly where a condition of over-ripe and dead cane is prevalent. In this study, we have noted that 102 of the 227 treatments represented, have one or more instances wherein an individual plot has a cane yield that is higher (by at least 2 tons) than its treatment average

and a quality ratio that is also better (by at least .2 ton) than the average. Thus, high tonnage cane, *per se*, does not necessarily mean poorer quality.

In the Amounts of Nitrogen group, we had thought that we might find a higher significance, as indicated by an increasingly greater amount of negative correlation, with the larger than with the smaller application of nitrogen in each test: somewhat as exemplified in Waipio T-1927, where a correlation of —.50, —.74, and —.97 is obtained for the 191-, 228- and 266-pound nitrogen treatments, respectively. As a matter of fact, we find more instances where the reverse is true, i. e., less significance or a lower amount of negative correlation with the highest than with the lowest nitrogen application. This is illustrated by Waialua 14AN-1929: for the plots receiving only 90 pounds of nitrogen, we have a significant negative correlation of —.82 whereas in the largest or 225-pound treatment, although such treatment resulted in an average gain of 20 tons of cane over the lower amount, the amount of negative correlation is —.61 and indicates less significance to any direct relationship between tonnage and quality ratio. Out of the 68 treatments represented in this group of nitrogen experiments, we find only nine that have a definitely poorer quality ratio associated with the higher plot yields of cane.

In the Amounts of Phosphate group, we find 3 out of 29 comparisons showing a definite negative correlation between T. C. A. and Q. R., and in the Amounts of Potash group, 4 out of 19, or only 20 per cent of the cases studied, show this relationship definitely. None of the groupings made show a greater percentage than this cited for potash, which is very small.

It would seem questionable whether the purposely introduced variables of these experiments, to which we are inclined to give credit for the yield differences involved, have in themselves had a definite effect on the quality ratio. We could cite many examples to show this lack of relationship, but one will suffice to show what we mean: In Waipio L1-1926, an NK plot which produced 72 tons of cane with a quality ratio of 8.3 is found adjacent to an NPK plot that yielded 80 tons with a quality ratio of 7.3; in another part of the same test, we have an NK plot giving 62 tons with a quality ratio of 8.0 that is next to an NPK plot credited with 67 tons of cane and a quality ratio of 9.9. Most certainly, the addition of P_2O_5 which we have reason to feel has increased the cane tonnage in both pairs of plots, cannot be credited with improving the quality ratio in one case and charged with spoiling it in the other, as these data indicate.

We find many instances within blocks of plots that have had the same treatment, where inconsistencies are evident. Thus, if the NPK plots of Waipio U-1927 are arranged in descending yield order and their respective quality ratios placed against such arrangement, we find it difficult to believe that the applied treatment is the cause of the variation in quality ratios observed. Similarly, if the quality ratios of the NP plots are arranged in order, and their respective tonnages placed against them, it is difficult to find any definite relationship between the tonnage and the quality ratio setup that might be a cause of the treatment that was imposed.

NPK Plots Arranged in Descending Order of Cane Yields	Respective Q. R.'s	NP Plots Arranged in Descending Order of Q. R.'s	Respective T. C. A.
86 tons	9.4	8.1	68 tons
83 "	8.6	8.7	71 "
81 "	8.6	8.9	75 "
79 "	8.3	9.1	56 "
79 "	8.2	9.1	71 "
77 "	8.6	9.5	69 "
72 "	8.5		
71 "	8.6		
54 "	9.0		

These facts serve to point out that the condition under test in our experiments is not always primarily responsible for the result obtained. Inherent soil effects, human errors, and weather influences are plausible suggestions for many of the discrepancies noted. Most certainly do we have an indication that direct cause and effect relations between cane tonnage and quality ratio have not as yet been established.

CORRELATION BETWEEN T. C. A. AND Q. R. IN FIELD EXPERIMENTS FROM WAIPIO AND WAIALUA

AMOUNTS NITROGEN	Treatment	n	r
Waipio C			
1930	A—150 lbs. N	8	—.64
	B—200 lbs. N	8	+.20
	C—250 lbs. N	8	—.20
Waipio C			
1929	A—250 lbs. N	8	—.56
	B—300 lbs. N	8	—.50
	C—350 lbs. N	8	—.49
Waipio C			
1927	A—192 lbs. N	8	—.90*
	B—230 lbs. N	8	—.58
	C—269 lbs. N	8	—.66
Waipio C			
1926	A—275 lbs. N	9	—.28
	B—300 lbs. N	9	—.37
	C—325 lbs. N	8	—.46
Waipio J			
1927	A—250 lbs. N	7	+.74*
	B—270 lbs. N	7	+.10
	C—300 lbs. N	6	—.01
	D—324 lbs. N	5	—.87*
Waipio T			
1926	A—250 lbs. N	7	—.51
	B—275 lbs. N	8	—.58
	C—300 lbs. N	7	—.49
Waipio T			
1927	A—191 lbs. N	8	—.50
	B—228 lbs. N	7	—.74*
	C—266 lbs. N	7	—.97*

* These correlations may be considered as definitely significant.

AMOUNTS NITROGEN	Treatment	n	r
Waialua 39 AN			
1931	A—200 lbs. N	8	—.52
	B—140 lbs. N	8	+.08
Waialua 36 AN			
1931	A— 70 lbs. N	9	—.45
	B—110 lbs. N	9	—.30
	C—150 lbs. N	9	—.43
Waialua 33 AN			
1931	A— 70 lbs. N	11	—.30
	B—110 lbs. N	12	+.07
	C—150 lbs. N	12	+.37
Waialua 3 AN			
1930	A—150 lbs. N	5	—.33
	B—200 lbs. N	5	+.55
	C —250 lbs. N	6	—.39
	D—300 lbs. N	6	—.09
Waialua 26 AN			
1930	A— 90 lbs. N	9	—.50
	B —125 lbs. N	8	—.75*
	C—160 lbs. N	9	—.28
Waialua 15 AN			
1929	90 lbs. N	6	+.17
	145 lbs. N	6	—.30
	200 lbs. N	6	—.06
	255 lbs. N	6	+.53
Waialua 18 AN			
1929	90 lbs. N	6	—.93*
	150 lbs. N	6	—.54
	210 lbs. N	6	—.94*
	270 lbs. N	6	+.19
Waialua 19 AN			
1929	150 lbs. N	5	—.40
	210 lbs. N	5	—.82
	270 lbs. N	5	+.32
Waialua 13 AN			
1929	90 lbs. N	6	—.45
	145 lbs. N	6	+.02
	200 lbs. N	6	—.90*
	255 lbs. N	6	+.10
Waialua 14 AN			
1929	90 lbs. N	6	—.82*
	145 lbs. N	6	—.32
	200 lbs. N	6	—.41
	255 lbs. N	6	—.61
Waialua 6 AN			
1929	90 lbs. N	6	0
	150 lbs. N	6	0
	210 lbs. N	6	—.59
	270 lbs. N	6	+.14
Waialua 2 AN			
1928	150 lbs. N	4	—.16
	200 lbs. N	4	—.30
	250 lbs. N	4	—.43
	300 lbs. N	4	—.89

* These correlations may be considered as definitely significant.

	Treatment	n	r
Waialua 3 AN 1928	150 lbs. N	4	+.59
	200 lbs. N	5	+.92*
	250 lbs. N	6	-.01
	300 lbs. N	6	—.22
AMOUNTS PHOSPHATE			
Waialua 32 AP 1931	A—No P_2O_5	10	—.46
	B— 70 lbs. P_2O_5	10	—.16
	C—140 lbs. P_2O_5	10	—.49
Waialua 30 AP 1931	A —No P_2O_5	9	—.11
	B—100 lbs. P_2O_5	9	—.48
	C—200 lbs. P_2O_5	9	—.56
	D—300 lbs. P_2O_5	9	—.64
Waialua 31 AP 1931	E—No P_2O_5	9	+.15
	F—100 lbs. P_2O_5	9	—.45
	G—200 lbs. P_2O_5	9	-.51
	H—300 lbs. P_2O_5	9	—.48
Waialua 24 P 1931	X— 70 lbs. P_2O_5	6	—.33
	A—111 lbs. P_2O_5	6	—.86*
	B—152 lbs. P_2O_5	6	—.008
	C—193 lbs. P_2O_5	6	+.20
Waialua 17 AP 1931	A—No P_2O_5	6	—.57
	B—100 lbs. P_2O_5	6	—.04
	C—200 lbs. P_2O_5	6	—.52
Waialua 28 AP 1930	A—No P_2O_5	9	—.27
	B—100 lbs. P_2O_5	10	—.42
	C—200 lbs. P_2O_5	10	—.52
	D—300 lbs. P_2O_5	9	—.22
Waialua 17 AP 1929	No P_2O_5	6	—.75
	100 lbs. P_2O_5	6	—.47
	200 lbs. P_2O_5	6	—.70
Waialua 5 AP 1929	70 lbs. P_2O_5	5	—.94*
	98 lbs. P_2O_5	5	—.60
	126 lbs. P_2O_5	5	—.08
	154 lbs. P_2O_5	5	—.88*
AMOUNTS POTASH			
Waialua 10 AK 1931	A—No K_2O	6	—.54
	B—150 lbs. K_2O	6	—.68
	C—300 lbs. K_2O	6	—.84*
Waialua 29 K 1931	A—No K_2O	7	—.69
	B—150 lbs. K_2O	7	—.84*
	C—300 lbs. K_2O	7	—.57

* These correlations may be considered as definitely significant.

AMOUNTS POTASH	Treatment	n	r
Waialua 10 AK			
1929	No K_2O	6	—.20
	100 lbs. K_2O	6	—.50
	200 lbs. K_2O	6	—.84*
Waialua 8 K			
1929	No K_2O	6	—.55
	100 lbs. K_2O	6	—.84*
	200 lbs. K_2O	6	—.70
Waialua 9 AK			
1929	No K_2O	7	—.24
	100 lbs. K_2O	7	—.69
	200 lbs. K_2O	7	—.70
Waialua 7 AK			
1927	No K_2O	2	—1.0 *
	100 lbs. K_2O	3	+.32
	200 lbs. K_2O	3	+.94
	300 lbs. K_2O	3	+.77
PLANT FOOD TESTS			
Waipio L1			
1926	N	14	—.12
	NP	15	—.27
	NK	13	—.39
	NPK	12	+.06
Waipio L1			
1928	N	11	—.58
	NP	11	—.82*
	NK	9	—.61
	NPK	8	—.55
Waipio U			
1927	NP	6	+.12
	NPK	9	+.08
Waipio V			
Using averages for	N	7	+.30
7 different years	NP	7	+.08
	NK	7	+.56
	NPK	7	+.40
Waialua 12 NPK			
1931	N	6	—.27
	NP	6	—.57
	NK	6	—.67
	NPK	6	—.91*
Waialua 11 PK			
1929	N	6	—.04
	NP	6	—.47
	NK	6	—.85*
	NPK	6	—.40
Waialua 27 HG			
1930	N only 160 lbs.	9	+.43
	HG 160 lbs.+70+70	9	+.05
Waialua 23 PK			
1930	A—N only	5	—.42
	B—NPK	5	—.52
	C—NPK	5	—.21

* These correlations may be considered as definitely significant.

PLANT FOOD TESTS	Treatment	n	r
Waialua 16 AHG			
1930	A—140-70-70	5	+.70
	B—190-140-140	5	—.33
Waialua 12 PK			
1929	N	6	—.45
	NP	6	+.76
	NK	6	+.82*
	NPK	6	—.33
Waialua 6 PK			
1927	N	6	—.33
	NP	6	+.20
	NK	6	—.85*
	NPK	6	—.64
FORMS OF NITROGEN			
Waipio D			
1930	NS	6	—.58
	AS	6	+.90*
	NL	6	—.39
	NS+AS	6	+.44
Waipio D			
1929	NS	6	—.78
	AS	6	—.49
	NL	6	—.73
	NS+AS	6	—.26
Waipio D			
1927	NS	6	—.10
	AS	6	+.05
	NL	6	+.11
	NS+AS	6	—.50
Waipio D			
1926	NS	6	—.74
	AS	6	—.50
	NL	5	—.64
	NS+AS	5	—.95*
Waipio L2			
1926	NS	4	+.66
	NL	4	—.20
Waipio L2			
1931	NS	4	—.80
	NL	4	—.65
Waipio R			
1930	NS	13	—.09
	Leuna	13	—.24
	Calurea	12	—.31
VARIETY TESTS			
Waipio A			
1927	H 109 checks	44	+.03
Waipio K			
1930	First 100 plots of H 109 in Variety test	100	—.10
Waipio L3			
1931	All H 109 check plots	17	+.42

* These correlations may be considered as definitely significant.

VARIETY TESTS	Treatment	n	r
Waipio S			
1929	H 109 check plots	9	—.39
	H 109 ratoon	9	—.54
Waipio S			
1930	Check plots of H 109 plant	4	—.07
Waialua 25 V			
1931	H 109	8	—.74*
	H 8965	8	+.13
Waialua 35 V			
1930	Waialua 4	4	+.04
	H 109	4	—.31
Waialua 34 V			
1931	H 109	6	+.32
	H 8994	6	—.70
Waialua 22 V			
1930	D 1135	4	—.47
	K 107	4	+.04
	K 202	4	+.88
	H 8965	4	+.03
	POJ 36	4	+.94*
	H 109	20	+.16
MISCELLANEOUS			
Waipio B			
1926	A—N ½+½	8	—.49
	B—N ¼+½+¼	8	—.91*
	C—N ⅓+⅓+⅓	7	—.39
Waipio B			
1927	A—N in 3 doses	12	—.61
	B—N in 2 doses	12	+.17
Waipio B			
1929	A—N in 4 doses	10	—.28
	B—N in 2 doses	10	—.53
Waipio B			
1930	A—N in 3 doses	12	+.07
	B—N in 1 dose	12	+.35
Waipio K			
1927	A—Early N	5	—.81
	X—Later N	5	+.41
Waialua 20 T			
1930	A—200 lbs. N ¼+¾	6	—.85*
	B—200 lbs. N ¾+¼	6	—.97*
	C—200 lbs. N ½+½	5	—.69
Waipio F			
1930	Residual molasses—10 tons	5	—.74
	Check	5	+.23
Waipio F			
1928	Seed	18	—.37
Waipio J			
1930	A—Conc. Fert.	11	—.67*
	B—Old materials	11	—.78*
Waipio L1			
1931	Fertilizer with seed	13	+.01
	No fertilizer with seed	13	+.03

* These correlations may be considered as definitely significant.

MISCELLANEOUS	Treatment	n	r
Waipio P			
1929	A—Irrig. 1 line	5	—.11
	B—Irrig. 2 lines	4	—.25
	C—Irrig. 4 lines	4	+.68
Waipio P			
1930	A, B, C } Same as 1929	5	+.37
		4	—.43
		4	—.40
Waipio T			
1930	CK—AS	4	—.85
	P_2O_5—AS	4	—.80
	Mud—AS	4	—.72
	CK—NS	4	—.97*
	P_2O_5—NS	4	—.71
	Mud—NS	4	—.95*

* These correlations may be considered as definitely significant.

Dwarf Disease of Sugar Cane*

By Arthur F. Bell
Pathologist, Bureau of Sugar Experiment Stations

Dwarf disease is the name which has been adopted for an apparently new and serious disease of sugar cane recently discovered in the Mackay district. Should this disease become widespread it would undoubtedly prove very destructive to certain varieties of cane, and this article has been written for the purpose of describing the symptoms of the disease and setting forth the situation for the benefit of cane growers.

History and Distribution

In 1930, Mr. A. P. Gibson reported that, as the result of a request received from a farmer, he and Messrs. Keogh and Osborn, of the Mackay Sugar Experiment Station, had inspected a field of plant P. O. J. 2714 and there found some 60 to 70 stools of cane affected with a disease with which they were not familiar. He further stated that in general appearance diseased plants resembled those infected with Fiji disease, but with the important distinction that no leaf galls were present. Two diseased stools were forwarded to this laboratory for examination and were received in good condition. Both consisted of dwarfed grass-like tufts, with yellowish streaked leaves, and greatly resembled extreme cases of Fiji disease, except that no leaf galls were present; they were also suggestive of the "lemon grass" stage of sereh disease, but with the additional feature of numerous yellowish leaf streaks. In our opinion the disease could not be classified as any disease as yet recorded in Australia, nor, in spite of certain resemblances to sereh and streak diseases, did it appear to be identical with any sugar cane disease heretofore described in any other part of the world.

A subsequent inspection of the infected field confirmed the impression that we had to deal with a distinct disease, and a survey of the surrounding district was undertaken by Mr. Osborn, who was later joined by Mr. Wood. The result of the survey indicated that the outbreak was quite restricted in its incidence, and was mainly confined to the Rosella district. The presence of the disease was eventually established in fifteen fields distributed over nine farms, while a few doubtful stools were seen and destroyed on three other farms. The amount of infection per field varied from a single stool to a maximum of slightly less than .5 per cent. Regular inspections of these farms were continued and diseased stools rooted out, with the result that at the last two inspections the disease was found on four farms only.

With one exception (but see below) the only variety found to be infected on these inspections was P. O. J. 2714, and in this particular case five diseased stools

* Reprinted from *Queensland Agricultural Journal*, Vol. XXXVII, pp. 9-17, 1932. (Plate 1 is not included in this article.)

of P. O. J. 213 were found, in addition to one stool of P. O. J. 2714. On this farm also four stunted stools of E. K. 28 were found and destroyed, but the observer was unable to state definitely that the disease was dwarf disease. In five of the nine definite cases of the disease the stocks of P. O. J. 2714 had been obtained from the farm on which the outbreak was first discovered, but the remaining farms had had no interchange of varieties. On one of these three, cuttings of P. O. J. 2714 were received and planted in 1927, and all available supplies from the original stock were planted in 1928 and again in 1929; no disease was noticed until 1931, when one diseased stool was found in the ratoons of the 1929 plant, and approximately thirty stools in the 1930 late plant. The owner of the farm on which the disease was originally found received three sticks of P. O. J. 2714 in 1927; these gave rise to well-grown stools, which in 1928 were harvested and planted out in three rows. This cane was used in 1929 to plant two small blocks, one of which remained healthy, but in the other the 60 to 70 diseased stools mentioned above were found in 1930. An examination of the ratoons of the three rows from which these plants were taken revealed the presence of three diseased stools. Of these stools two were adjacent stools in one row, while the third was immediately opposite in the next row.

From the point of view of varietal susceptibility it is important to note that this particular farmer reported that early in 1931 he dug out a number of similarly diseased stools of H. Q. 426 (Clark's Seedling) in a field adjoining diseased P. O. J. 2714. This field was inspected on the occasion of the next visit, but no further infected stools were found. No definite observations on varietal resistance have been possible, but Q. 813 grown immediately adjoining the worst-infected field of P. O. J. 2714 has remained disease-free throughout.

Symptoms as Exhibited by the Variety P. O. J. 2714

The leaves, particularly the younger leaves, of diseased canes are marked with fine longitudinal yellowish stripes. The stripes are usually short, ½ to 2 inches long, but they may often be as much as 6 inches in length; they follow the direction of the veins and are about 1/16 inch wide, but may run together to give moderately wide bands, especially at the margin of the leaves. These markings are always more pronounced at the base of the leaves, and are not evenly distributed over the leaf surface as a rule. A good idea of the appearance of these leaf symptoms may be obtained by reference to Plates 2 and 3.

The leaves of diseased canes are stiff and erect, thus imparting a fan-like appearance to the cane top; the spindle and the younger leaves are usually twisted and deformed, of a lighter color, and shorter than normal (Plate 4). As in the case of mosaic, there is a progressive masking of the streaks in passing to the older leaves, but with dwarf disease the older leaves are of a darker green than normal.

The most striking symptom is seen in the case of primary infection. Here the stool consists of a number of stunted shoots which form no cane; the leaves are erect, stunted, and clustered, and bear the typical yellowish streaks with, as a rule, scalded or reddish tips, margins, or stripes, and later becoming frayed and torn.

PLATE 2.

Leaves of diseased P. O. J. 2714, photographed by transmitted light. Streaks on left-hand leaf more closely resemble those of streak disease than is usually the case. Note uneven distribution of streaks in right-hand leaf and presence of yellowish marginal band on both leaves.

PLATE 3.
Similar to Plate 2 but photographed by reflected light.

PLATE 4.

Stalk of P. O. J. 2714, illustrating production of fan-like top following secondary infection.

The majority of the plants which we have produced by planting infected cuttings have died out without producing many shoots, but those which persist eventually produce a greater number of small shoots and resemble a tuft of grass. This stage of the disease much resembles extreme cases of sereh and Fiji diseases (Plate 5). Ratoon plants from diseased stools present a similar appearance and also form the grass-like cluster, with no production of cane. The life of such stunted shoots is usually very short.

In cases of apparently secondary infection, growth ceases suddenly and the top of the stalk tapers off to a point, forming the fan-like top. Such stunted stalks are soon outgrown by the healthy stalks in the same stool, and the upper internodes become sunken. The general appearance of such canes is again very similar to cases of secondary infection Fiji disease. There is no marked shooting at the eyes or production of aerial roots by the diseased stalks, nor is there any discoloration of vascular or storage tissue, nor, in fact, any macroscopic abnormality.

Histological Examination

A preliminary histological examination has failed to demonstrate the presence of any pathogenic organism within the tissues of diseased plants, but has revealed certain structural abnormalities which should form an interesting subject for subsequent examination. No definite abnormalities were observed in either stems or leaves of plants in which the infection was secondary, but a marked derangement of the tissues occurs in the vascular bundles of the leaves of the extremely stunted plants which result from primary infection. The derangement occurs to some extent in minor bundles, but is particularly associated with the major bundles, of which a typically distorted member is illustrated in Plates 7 and 8.

The bundle may be considerably enlarged, very irregular in shape, and frequently fused with an adjoining minor bundle. The chlorophyll-bearing sheath is incomplete, as a rule, and may be represented by a very few cells or be entirely absent in extreme cases. Within the bundle there is an abnormal development of comparatively thin-walled lignified cells which frequently radiate through the bundle in two or more strands, bringing about distortion and altering the relative positions of component tissues. Phloem may be almost entirely absent and confined to one of the resultant sectors, or may be found scattered in more than one sector or at the ends of the lignified strands. The walls of the cells of the lignified inner sheath surrounding the phloem appear thinner than is the case in normal cane, and the sheath is completely disrupted, but whether the strands of woody cells have their origin in this particular tissue has not been established. (See Plate 9.)

Relation to Other Diseases

The disease has features in common with Fiji, sereh, and streak diseases. The presence of the yellowish leaf streaks and the absence of galls on the under surface of the leaves—which are particularly prominent in Fiji-diseased P. O. J. 2714—ruled out the possibility of identity with this disease. Similarly the presence of these leaf streaks and the absence of any internal discoloration and adventitious

PLATE 5.
Typically stunted plant stool of P. O. J. 2714, 18 months old.

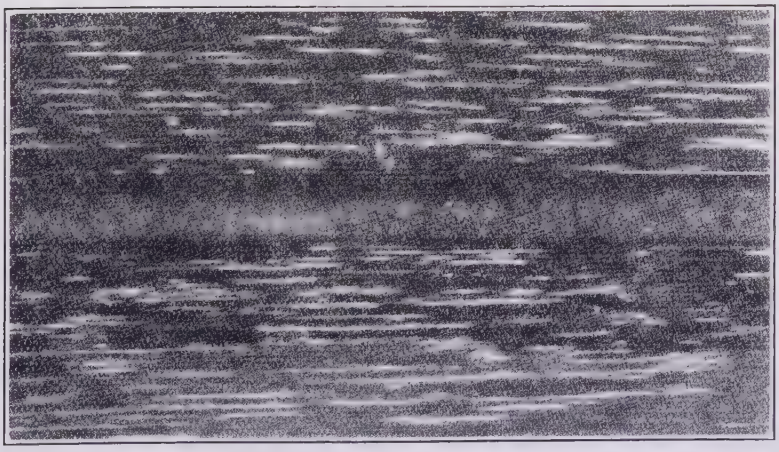


PLATE 6.
Streak disease in Uba. Compare with Plates 2 and 3.

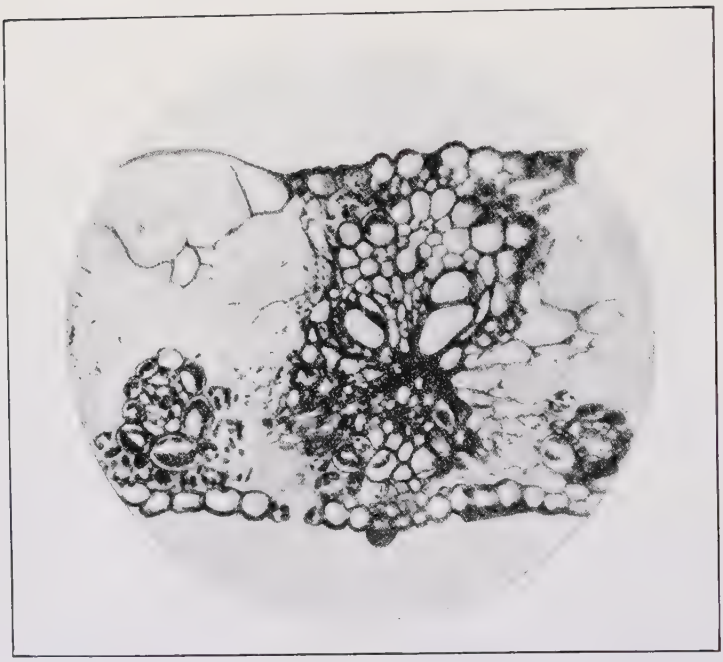


PLATE 7.

Cross section of major vascular bundle from leaf of P. O. J. 2714, showing abnormal development, presence of radiating strands of lignified tissue, and incomplete bundle sheath. *From a freehand section made and photographed by Mr. Cottrell-Dormer.*

root production strongly discounted the possibility of identity with sereh. In so far as streak disease was concerned, there appeared from the published report of Storey* to be considerable differences in color, length, and distribution of the leaf streaks, as well as the degree of stunting of diseased plants. Particular significance was attached to these differences in view of the statement by Storey (page 7) that "The symptoms of streak disease show a remarkable uniformity throughcut all varieties of cane affected." At that time, however, P. O. J. 2714 did not appear to have been exposed to streak disease in South Africa, and thus it was possible that the variations in symptoms might be due to a difference in varietal response. Accordingly, photographs, preserved leaves, and a description of the external symptoms were forwarded to Dr. H. H. Storey of the Amani Institute, and Mr. A. P. D. McClean of the Natal Herbarium, and their opinion sought as to the identity of the disease. Both these gentlemen have expressed themselves as definitely of the opinion that dwarf disease is distinct from streak, although the leaf markings may bear a close resemblance at times. Dr. Storey directed attention to the following important differences between the two diseases:

1. The stiff fan-like top occurs only in young streak-diseased Uba, and in later growth diseased plants are not noticeably different in habit from healthy plants.
2. The stripes of streak disease are white rather than yellow.
3. They are usually only a few millimetres long and rarely more than an inch in length.
4. The leaf markings are evenly distributed over the leaf in the case of streak.
5. There is no deformity of the inner leaves, and older leaves do not assume a darker green than normal.
6. There is no masking of streak symptoms in older leaves.
7. Such abnormally severe stunting has not been observed with streak, nor do shoots die prematurely.
8. Secondary infection causes no sudden cessation of growth.
9. Shrinking of internodes has not been noted.
10. Ratoons grow normally after an initial stunted stage.

Mr. McClean expressed similar views, and also stated that he has observed no case of streak disease in P. O. J. 2714, although this variety is now being grown in districts where 100 per cent infection with streak may commonly be expected in susceptible varieties such as Uba.

In January, 1931, we were favored with a visit from Mr. E. F. S. Shepherd, Botanist in the Department of Agriculture, Mauritius. After inspecting diseased plants Mr. Shepherd furnished us with a report in which he made, inter alia, the following remarks:

"The streaks of dwarf disease are, however, in my opinion, usually longer than those encountered in streak disease and are not so uniformly distributed over the surfaces of affected leaves. The streaks of streak disease do not tend to fuse laterally to the same

* Storey, H. H. "Streak Disease of Sugar Cane." Union of South Africa, Department of Agriculture, Science Bulletin, No. 39, 1925.

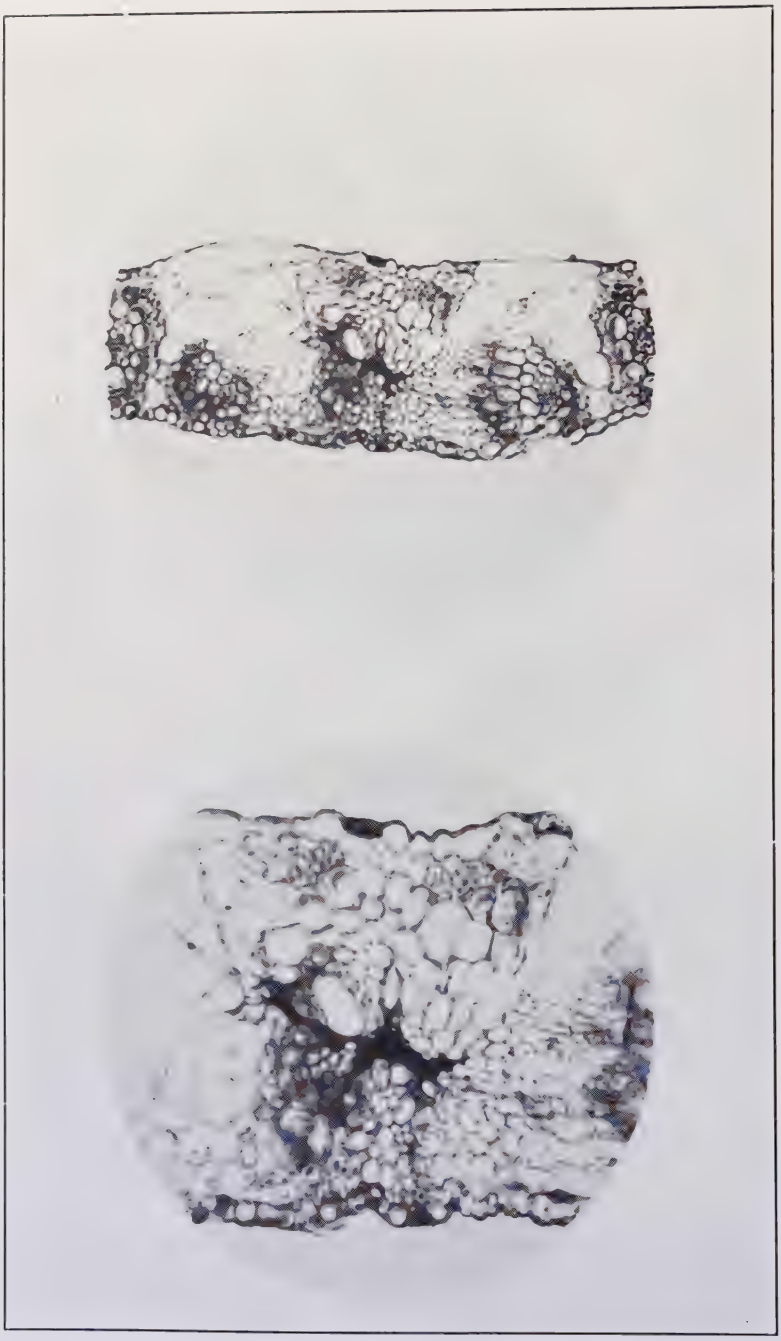


PLATE 8.

Transverse sections of leaves of P. O. J. 2714 affected with dwarf disease similar to that shown in Plate 7. The lower figure (x190) is an enlargement of a portion of the upper figure (x95). Preparations by W. Cottrell-Dormer. Photomicrographs by D. M. Weller.

Figures shown in Plates 8 and 9 are from slides furnished by Arthur F. Bell, January, 1932.

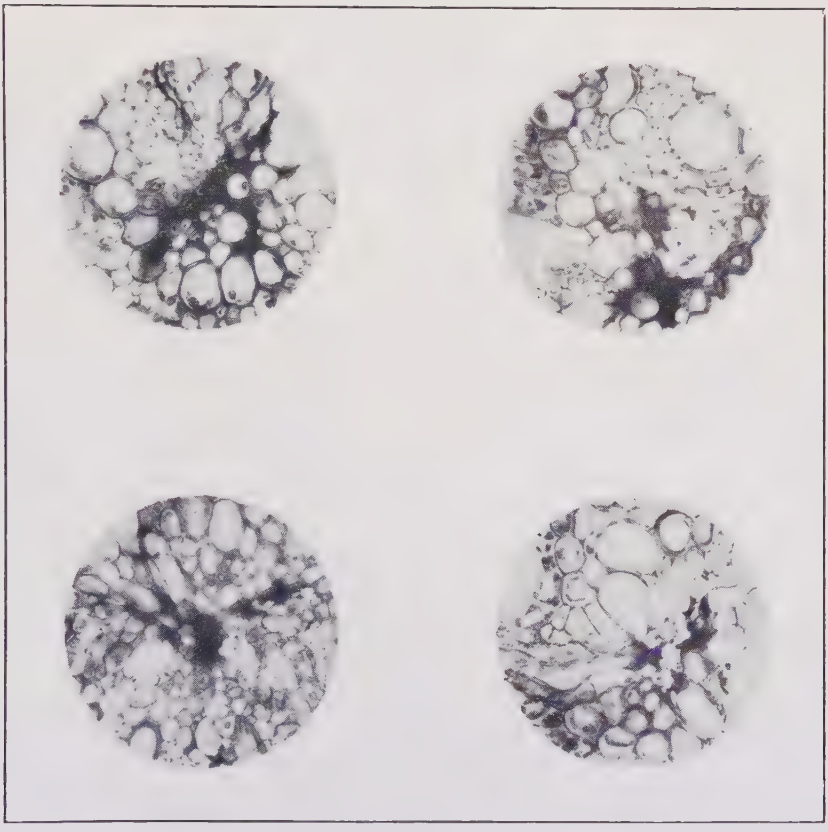


PLATE 9.

Transverse sections of major bundles of leaves of P. O. J. 2714 affected with dwarf disease (x250). The cause of the disease apparently prevented the complete differentiation of the tissues of the bundles and resulted in abnormal bundles composed chiefly of lignified tissues. Preparations by W. Cottrell-Dormer. Photomicrographs by D. M. Weller.

extent as do those of dwarf disease. The broad chlorotic bands towards the edges of leaves of dwarf disease affected canes do not, to my knowledge, occur in cases of streak disease, nor is there such a severe stunting of the shoots. Streak disease does not, to my knowledge, result in the death of shoots, which seems to be a constant character of dwarf disease. Dwarf disease has undoubtedly all the characteristics of a virus affection, but I am of the opinion that it is different from streak disease.''

Nature and Origin of the Disease

The origin and cause of this disease are, as yet, matters for speculation only. It certainly has all the external appearance of being a disease of the virus degeneration disease type, and derangement of vascular tissue is frequently a concomitant of such diseases, but beyond this nothing definite can be said. In the preliminary examination in the field Mr. Wood was unable to find any associated organisms, but reported a necrosis of phloem tissue in the leaves of plants produced by the planting of diseased setts. In the laboratory a detailed histological examination has failed to demonstrate the presence of associated fungi or bacteria, nor have any attempts to isolate an organism been successful to date; but this phase of the work will be continued.

The presence of the disease cannot be correlated with any particular soil type, and planting of diseased cuttings under widely different conditions has always given rise to diseased plants, while parallel plantings of healthy cuttings have given rise to healthy plants in each case. So far the planting of cuttings from apparently healthy canes in diseased stools has also given rise to healthy plants. From the results obtained by planting infected setts it seems unlikely that there is any prolonged masking of symptoms in the case of primary infection; assuming this point of view to be correct, secondary spread has been observed in a number of fields. The rate of spread has been comparatively slow and similar to what would be expected in the case of mosaic disease in a susceptible variety under similar field conditions. The results of secondary spread were most obvious during March and April, which is also a point of similarity with the spread of mosaic. Attempts at mechanical transmission by the use of the pinprick method developed by Sein* for the transmission of mosaic disease have so far given negative results.

Investigational work has been hampered by the fact that the outbreak occurred 600 miles from the laboratory, and also that as far as practicable diseased stools have been uprooted as soon as discovered. Attempts to maintain suitable experimental material in Brisbane have not been very successful, owing to the failure to produce plants consisting of other than small tufts of yellowish dying leaves; and pressure of other work has prevented the investigation of possible insect spread by the resident entomologist.

Three cuttings of each of the varieties P. O. J. 2714 and P. O. J. 213 were introduced from Java in January, 1922, along with P. O. J. 36, P. O. J. 100, P. O. J. 213, S. W. 3, D. I. 52, and F. 90. These canes were planted in the nursery of the Bundaberg Experiment Station and were grown under close supervision for some years, but no disease other than gumming disease was ever observed. P. O. J.

* Sein, Francisco. ''A New Mechanical Method for Artificially Transmitting Sugar Cane Mosaic.'' Journal, Department of Agric., Porto Rico, Vol. XIV, No. 2, p. 49, 1930

2714 and P. O. J. 213 from this stock are still being grown in the Bundaberg district, but have at no time exhibited symptoms of dwarf disease. Cuttings of these canes were sent to the Mackay Station in 1924 and propagated until 1927, when the first distribution was made. During the period 1927-29 many thousands of cuttings were distributed from Mackay Station to farmers in all parts of the State. Of the hundreds of farms to which the cane was distributed dwarf disease appeared on only four, which were all situated in the same locality (the plants on the five other positive and two doubtful farms were obtained from one of these four). On one of these four farms the disease did not appear until the second planting (three contiguous stools), and on another not until the third planting (one stool); the disease is so striking in appearance that it does not appear probable that it would be missed in small plantings. On each of the remaining two farms only a single stool was found, but these were found in the first planting.

From a consideration of the above facts there does not appear to be any likelihood of the disease having been introduced in cuttings from Java, quite apart from the fact that such a disease has not been reported from Java or any other country. The origin of the disease therefore remains a mystery; of the possible explanations of its appearance the most feasible at present is that the disease has been present in wild plants or other cultivated plants, and has been transmitted to sugar cane following the growing of susceptible varieties. Such a possibility is, of course, by no means remote, and there are numerous instances of sugar cane becoming infected with mosaic disease in this manner. Against this, however, is the fact that in spite of careful searching no suspicious symptoms have been observed on adjacent grass and weeds, but in this connection it should be borne in mind that the extremely droughty conditions prevailing over the past two seasons have been distinctly unfavorable for this type of observation.

Control

From the rather limited field observations which it has been possible to make, this disease appears similar to mosaic and Fiji diseases in many respects, including the time and rate of spread. For this reason the methods which are so successfully used in the control of these diseases commend themselves for use in this instance. It is accordingly recommended that the following measures should be put into operation by growers:

1. Study the symptoms of the disease in order to be able to recognize it in the field.
2. Carefully inspect, or have an officer of the Bureau inspect, any field (especially in the case of P. O. J. 2714, P. O. J. 213, E. K. 28, and Clark's Seedling) which it is proposed to use as a source of plants, and reject this field entirely if even a single stool of dwarf disease is found.
3. Inspect young plant and ratoon cane regularly and uproot any diseased stools as soon as they are found.
4. Keep fields and headlands as clean as possible.

5. Avoid planting P. O. J. 2714 if other varieties will give satisfactory yields.
6. In any case of doubt as to the presence of the disease, refer the matter to the nearest officer of the Bureau of Sugar Experiment Stations.

[J. P. M.]

The Cane-Killing Weed*

By Arthur F. Bell, *Pathologist;* W. Cottrell-Dormer, *Assistant Pathologist*

Although the existence of *Striga* as a parasite of sugar cane in Queensland has been recorded for a number of years, no detailed descriptions or illustrations have been published, with the result that the appearance and effects of the weed are still unfamiliar to most sugar farmers and technical workers in this State. Consequently, the following notes have been compiled to supplement the excellent illustrations which were executed by Mr. I. W. Helmsing under the general supervision of Mr. Henry Tryon, late Entomologist and Vegetable Pathologist in the Department of Agriculture. We are indebted to Mr. Robert Veitch, Chief Entomologist in the Department of Agriculture, for his courtesy in making available the services of Mr. Helmsing for the preparation of these plates.

History and Distribution

These weeds are classified botanically within the genus *Striga* and are of particular interest, inasmuch as they are members of the comparatively small group of flowering plants which are parasitic upon other plants. They are fairly common throughout the tropics, occurring abundantly, according to Pearson(5), in Tropical Africa, Egypt, Madagascar, Arabia, Ceylon, India, Siam, Java, and China. The term "cane-killing weed" is a general term applied to the members of this genus which are found parasitic upon the roots of sugar cane in Queensland.

In South Africa one species (*Striga lutea* Lour.), commonly known as the witchweed, has been recognized as a serious parasite of the roots of maize for many years. The effects of the parasite are particularly severe if the maize is planted near the time of germination of the witchweed seeds, so that it becomes infected in the young seedling stage. The witchweed is also found as a parasite of sugar cane in Natal, but to a much less extent than on maize.

Striga as a root parasite of cane was reported from India in 1921(4), and was stated to have first been noticed in the Patiala State Territory about 1914. In 1920, reports were received of a new disease in the sugar cane fields of the "Bet" lands of the river Sutlej. Upon investigation it was found that the cane roots were being attacked by flowering parasites, of which two were observed—namely, *Striga densiflora* Benth. and *Striga euphrasioides* Benth. In the course of the investigation, it was found that the parasite disappeared when the fields were rotated to cotton, and that therefore partial control had been unconsciously practiced in the past.

This parasite is also found on sugar cane in Mauritius, and in 1928 *Striga hirsuta* was reported as causing considerable damage on one estate(6).

* Reprinted from the *Queensland Agricultural Journal*, Vol. XXXVI, pp. 463-473, 1931.

Specimens of *Striga* spp. were collected early in the botanical history of Queensland, and *S. hirsuta, S. parviflora,* and *S. curviflora* were included in an early catalogue of plants(2), at which time they appeared to be generally distributed over the State. The first record of these plants as parasites of cane appears to have been in 1916, when Tryon(7) briefly reported *S. parviflora* as attacking cane in the Degilbo district. In 1924, the weed was found independently by Cottrell-Dormer at Carmila(2). Since that time at least three varieties or species of the weed have been found in various parts of the Burdekin, Proserpine, Mackay, and Bundaberg districts.

We have, on several occasions, found the weeds associated with wild grasses, but in no case was any apparent stunting produced. They, therefore, are an example of indigenous parasites which have established a state of equilibrium with their hosts, but the state of equilibrium has now been disturbed by the introduction of a new cultivated host plant which has proved susceptible and allowed the parasites to gain the ascendency.

Appearance of the Disease

As a rule the areas of infection are roughly circular in shape, with a diameter of a few yards. The damage to the crop may range from an almost imperceptible stunting, in the case of very light infection, to the premature death of the cane. In a typical case the stools are markedly stunted, with small sparse tops and clinging trash. The stunted green leaves stand out stiffly from the crown and the more recently dead leaves tend to stand out at an angle rather than hang loosely. As a result, the leaf blades present an appearance similar to the spokes of a wheel. The older leaves hang stiffly down the stalk. In common with most root diseases, the symptoms produced in the cane by these parasites are not particularly definite. The clinging trash may be responsible for the shooting of the aerial roots, but even in the recently dead canes there are no visible symptoms such as reddened fibres, etc. The root system does not appear to be reduced to any appreciable extent.

During the summer months the small weeds may readily be found in clusters at or near the base of the stools, while in some cases they may be generally distributed in the interspaces also. If a stool and the associated weeds are dug up and the soil carefully washed away, the white roots of the parasite will readily be distinguished from the dark-brown roots of the cane. Both sets of roots are much intertwined, and on careful examination it will be seen that the roots of the parasite are attached to those of the cane by means of small cup-like swellings. The number of such attachments per weed may vary from one to many.

After the death of the weeds in the autumn a careful search may be necessary before the dried bluish black plants may be found.

Description of the Parasites

The following botanical description of the genus *Striga,* to which these weeds belong, is taken from Hooker(3):

"Usually scabrid herbs, discolored or black when dry. Leaves, lower opposite, upper alternate, linear, entire, rarely toothed, sometimes reduced to scales. Flowers axillary

or the upper in bracteate spikes often 2-bracteolate. Calyx tubular, strongly 5-15 ribbed, 5-toothed or -fid. Corolla-tube slender, abruptly incurved at or about the middle or top; limb spreading, 2-lipped, upper lip usually short notched or 2-fid; lower, the inner in bud, 3-fid. Stamens 4, didynamous, included; anthers 1-celled, vertical, dorsifixed, bases obtuse, connective sometimes mucronate. Style thickened above, stigma simple. Capsule subglobose or oblong, loculicidal; valves entire, septiferous, separating from the placentas. Seeds very numerous, ovoid or oblong, reticulated. Species about 18, in the hotter regions of the Old World.''

As stated above, at least three distinct weeds have been found parasitic on cane in Queensland, but owing to the rather ill-defined differences between some of the recorded species, and in the absence of type specimens, we have not attempted to identify them. The chief differences are in flower color and habit, viz.:

(a) Erect, flowers light-blue or lilac.
(b) Trailing on ground, flowers light-pink.
(c) Erect, flowers light-pink.

The general characteristics of the weeds may be studied in detail by references to Plates 119 to 124. The above-ground stems are green, circular at the base, but becoming quadrified higher up (Plate 120, figs. 2 and 3; Plate 121, fig. 4). The leaves are small, elongated, and green, the lower leaves being opposite and the upper alternate. Both stem and leaves become bluish black in color when dried. Flowering takes place freely during the late summer; the flowers are small, sessile, and borne in the form of long interrupted spikes. The seeds are borne in small cylindrical capsules (Plate 121, fig. 6) which split longitudinally and liberate their contents. The seeds are very small (about one thirty-second of an inch long), light, and are produced in extremely large numbers. The underground portions of the stem are white, fleshy, and branched, and bear whitish scale-like leaves (Plate 119, fig. 2); the roots are light-colored and much branched and the rootlets bear root hairs, although these are not present in large numbers.

The complete details of the life history of these parasites are not available, but, according to Pearson(5), it is essentially as follows: The seed falls upon the ground in late autumn or early winter and remains dormant until the early spring, when it germinates. The root of the young seedling grows out and produces small whitish spherical bodies, or haustoria; when the root comes in contact with a root of the host plant it becomes affixed thereto by these haustoria (Plate 119), which then send forth outgrowths which burst through the outer layers of the root and penetrate to the vascular system. On examination of a section cut through both root and haustorium the vascular bundles of the parasite may be traced through the haustorium and outgrowths into the vascular system of the cane root, thus forming a continuous vascular system between host and parasite. In the first few weeks of its existence the parasite does not appear above ground and the leaves remain whitish and rudimentary, but once the aerial stalks appear above ground their subsequent growth is rapid.

Since the leaves are green, it follows that this parasite must be able to carry on photosynthesis during the above-ground period of its existence, and the presence

of some root hairs would enable it to absorb a certain amount of water and plant foods from the soil as well as from the roots of the host plant. It must therefore be classed as a semi-parasite, at least during the later period of its existence. It is generally assumed (4 and 5) that the stunting of the cane plant is due to the loss of water and plant foods sustained by the host, but we have frequently seen cane stools 3 feet high killed by a small number of weeds, the total dry weight of which would not exceed that of one or two cane leaves. In a recent outbreak on the Burdekin, in which this condition was observed, the cane had been grown under regular irrigation and had suffered no check in growth. The remainder of the field yielded 45 tons per acre, for a one-year crop, while in a patch several yards in diameter the cane had been killed when about 3 feet high. We are therefore inclined to the view that the weed must elaborate some substance toxic to the cane plant.

Transmission and Control

The cane-killing weed is an annual and the whole plant dies after flowering and the production of seed. It is propagated by means of these seeds, which, being small and light, are easily carried by the wind and drainage and irrigation water.

Owing to their intimate association it follows that any practice, such as poisoning, which will kill the parasite is also likely to kill the cane. If the total area attacked is not large, every effort should be made to prevent the weeds from flowering and setting seed which will infect the next year's crop. This may be effected by chipping, but owing to the fact that the underground stems are constantly sending up fresh aerial shoots it is necessary to inspect frequently and chip when required. The seeds are sensitive to heat, and the burning of trash will assist in killing all seeds above or near the surface of the ground. Where the crop is heavily infected, it is recommended that it should be ploughed out and the ground rotated to legumes, which are not attacked. Under these conditions no fresh seed will be set in that season and few, if any, of the previous season's seed may be expected to survive.

References Cited

1. Bailey, F. M. Catalogue of the Indigenous and Naturalized Plants of Queensland, 1890.
2. Cottrell-Dormer, W. Reports in Queensland Agricultural Journal, 1924.
3. Hooker, J. D. The Flora of British India, Vol. IV, p. 298. 1885.
4. Luthra, J. C. Striga as a root parasite of cane. Agric. Jour. of India, Vol. XVI, Part 5, pp. 519-23. 1921.
5. Pearson, H. H. W. The Problem of the Witchweed. Dept. of Agric., South Africa, Bull. No. 40. 1929.
6. Shepherd, E. F. S. Ann. Rpt. Dept. Agric. Mauritius (Botanical Section). 1928.
7. Tryon, Henry. Report of Entomologist and Pathologist, Ann. Rpt. Dept. Agric., Queensland, 1915-6.

(J. P. M.)

Description of Plates

PLATE 119

Fig. 1.—Young seedlings attached to the roots of the host plant by means of small cup-shaped haustoria

Fig. 2.—Parasite during underground period of existence. Note white fleshy stems, rudimentary leaves, and light colored roots attached by means of haustoria to the dark sugar cane roots, x 2.

PLATE 120

Fig. 1.—Underground stem. Natural size.

Fig. 2.—Junction of underground and aerial stems; the latter is green, round, and bears elongated green leaves. Natural size.

Fig. 3.—Upper portion of aerial stem, the stem is now quadrifid and the leaves alternate. Natural size.

PLATE 121

Specimen from Bundaberg; habit erect, flowers light-pink.

Fig. 1.—Inflorescence. Natural size.

Fig. 2.—Calyx, x 4.

Fig. 3.—a. bract; b. and c. bracteoles, x 4.

Fig. 4.—Portion of upper stem showing quadrifid nature.

Fig. 5.—Seeds, x 17.

Fig. 6.—a. capsule, x 2; b. cross section of capsule, x 4; c. empty capsule after splitting longitudinally and liberating the seeds, x 4.

Fig. 7.—Flower, dissected to show arrangement of floral parts, x 3.

PLATE 122

Specimen from Mackay; habit erect, flowers light-blue.

Fig. 1.—Inflorescence. Natural size.

Fig. 2.—Calyx, x 4.

Fig. 3—a. bract; b. and c. bracteoles, x 4.

Fig. 4.—Flower bud, x 2½.

Fig. 5.—Flower dissected to show arrangement of floral parts, x 3.

Fig. 6.—Seed, x 17.

PLATE 123

Specimen from Proserpine; habit erect, flowers light-blue.

Fig. 1.—Inflorescence. Natural size.

Fig. 2.—Calyx, x 4.

Fig. 3.—a. bract; b. and c. bracteoles, x 4.

Fig. 4.—Extremity of tooth of calyx. Enlarged.

Fig. 5.—Seed, x 17.

Fig. 6.—Flower dissected to show arrangement of floral parts.

PLATE 124

Specimen from Burdekin; habit trailing, flower light-pink.

Fig. 1.—Inflorescence. Natural size.

Fig. 2.—Calyx, bract, and bracteoles, in situ, x 2.

Fig. 3.—Calyx, x 4.

Fig. 4.—a. bract; b. and c. bracteoles, x 4.

Fig. 5.—Arrangement of floral parts, x 2.

Fig. 6.—Protective appendages on margin of bract. Greatly magnified.

PLATE VII.

Photograph of typical young cane-killing weed shoots taken shortly after harvesting in a Proserpine cane field. The two-shilling piece indicates relative size. (Taken from reprint from *Queensland Agricultural Journal*, November, 1931.)

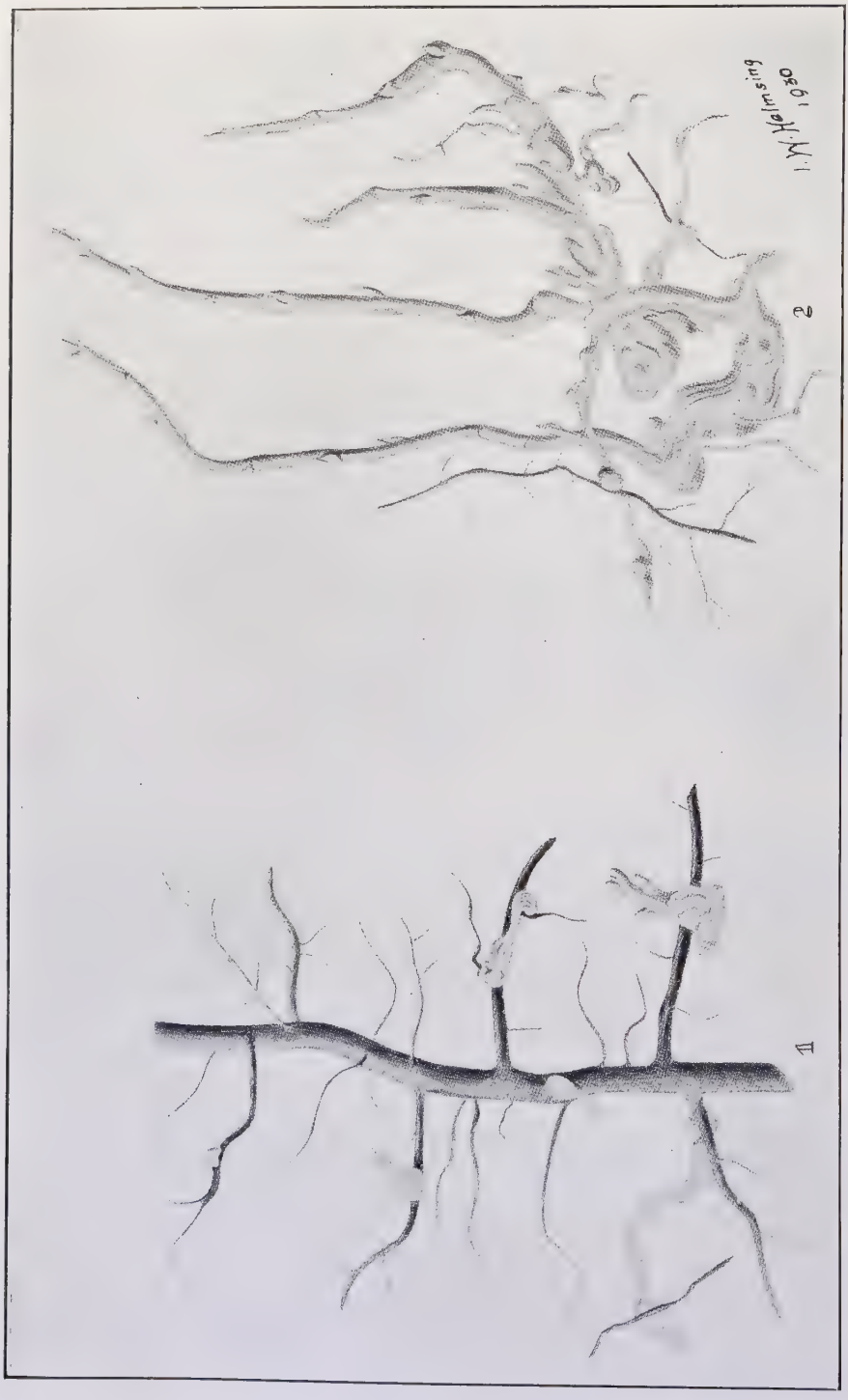


PLATE 119.
(For description of plate, see page 225.)

PLATE 120.
(For description of plate, see page 225.)

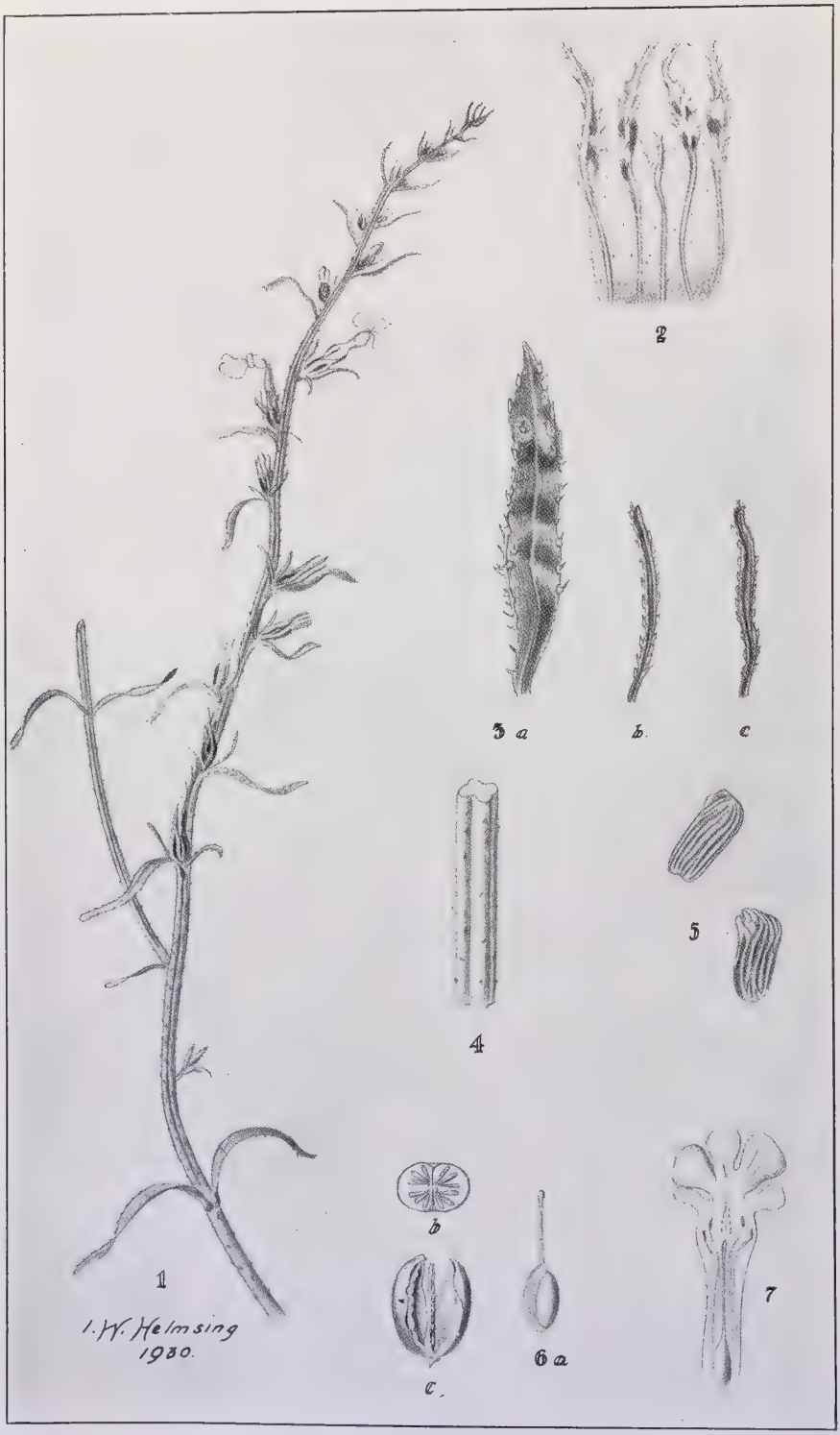


PLATE 121.
(For description of plate, see page 225.)

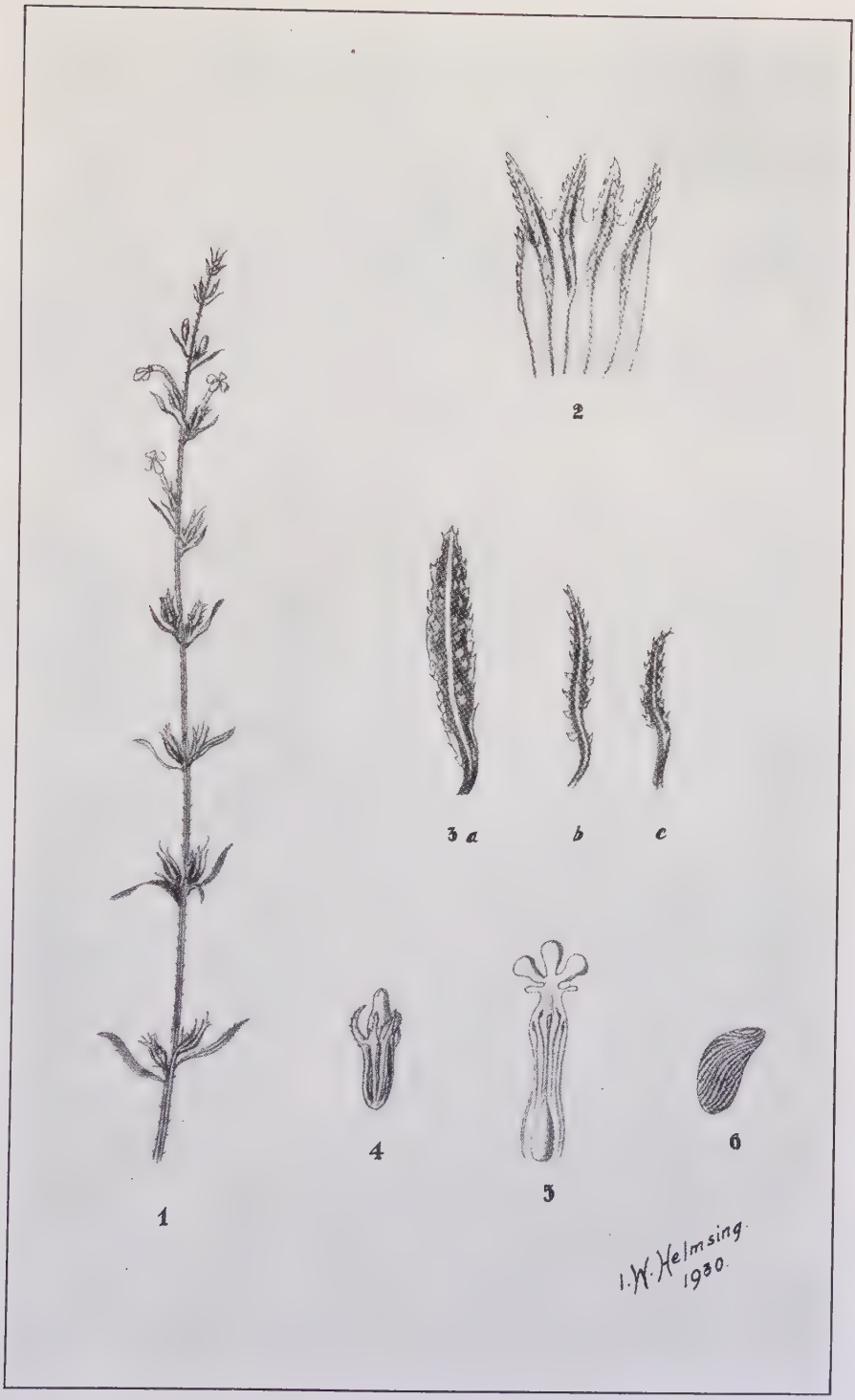


PLATE 122.
(For description of plate, see page 225.)

PLATE 123.
(For description of plate, see page 225.)

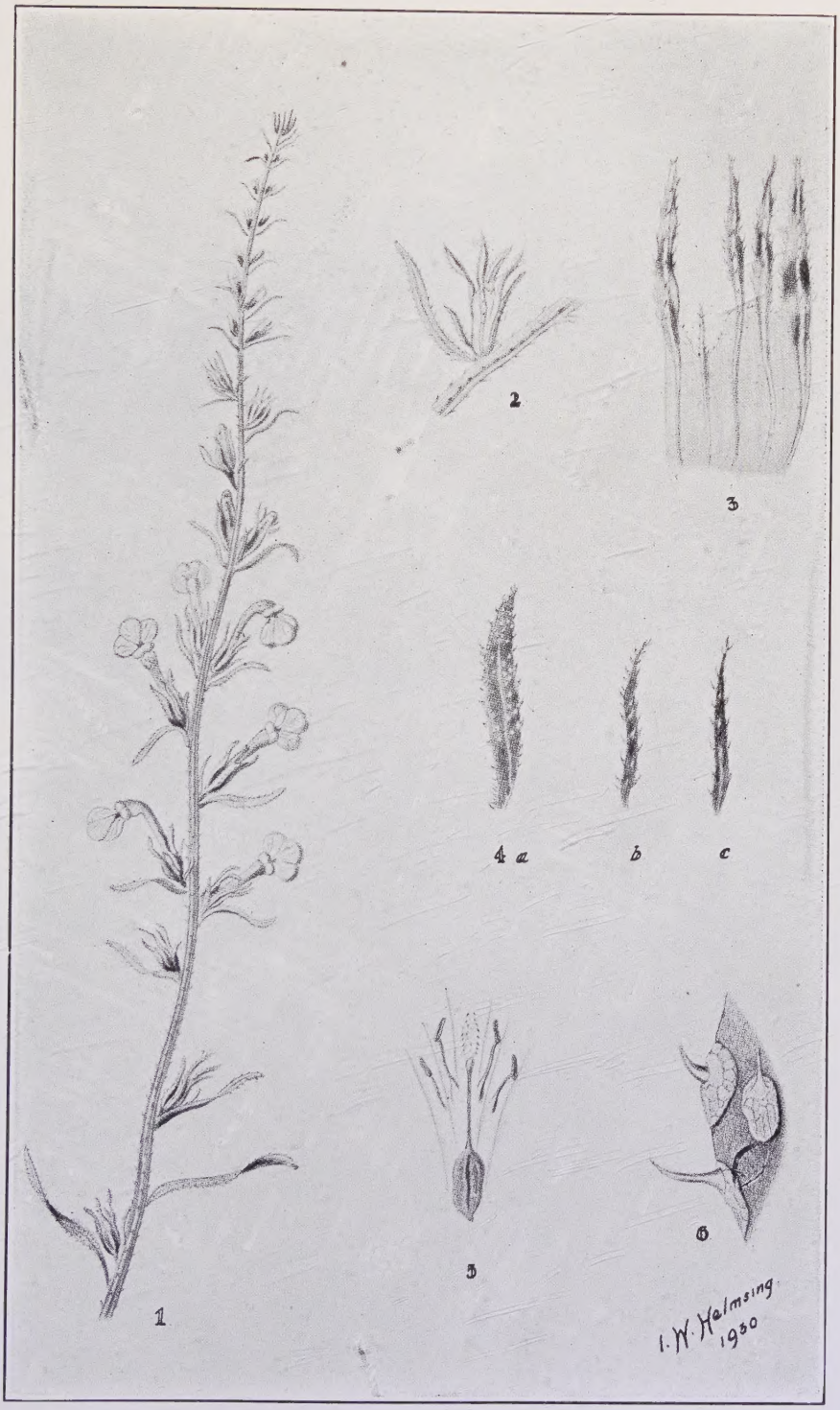


PLATE 124.
(For description of plate, see page 225.)

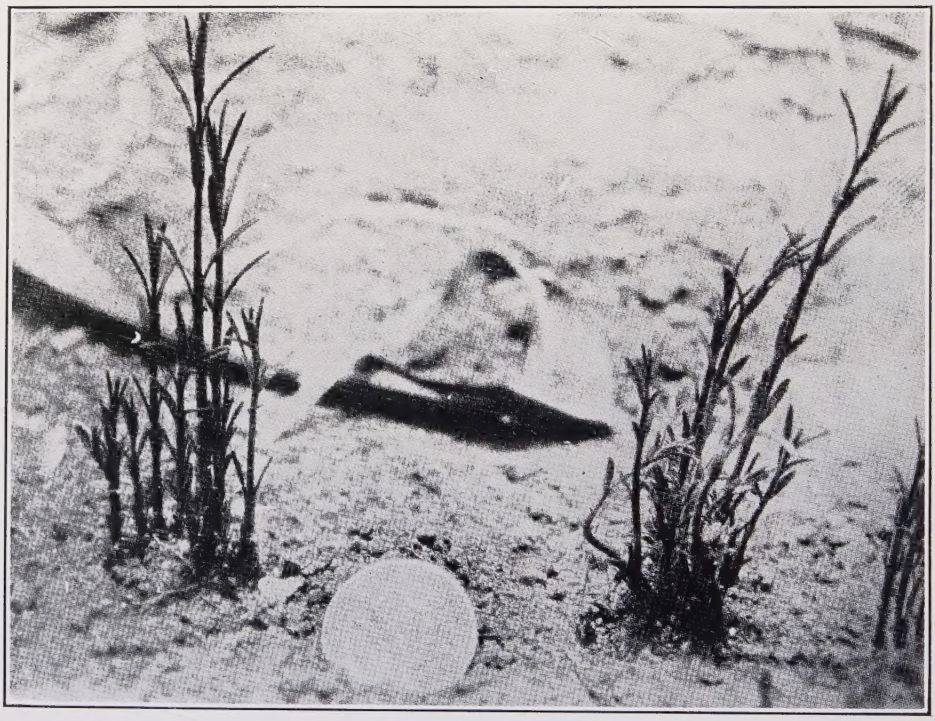


PLATE VII.

(For description of plate, see page 225.)

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
DECEMBER 16, 1931, TO MARCH 15, 1932

Date	Per Pound	Per Ton	Remarks
Dec. 16, 1931	3.105¢	$62.10	Cubas, 3.10, 3.11.
" 18	3.10	62.00	Cubas.
" 21	3.09	61.80	Porto Ricos.
" 22	3.095	61.90	Philippines, 3.09, 3.10.
" 23	3.10	62.00	Porto Ricos.
" 28	3.12	62.40	Porto Ricos.
" 29	3.14	62.80	Porto Ricos, 3.13; Cubas, 3.15.
" 30	3.18	63.60	Cubas.
" 31	3.20	64.00	Cubas.
Jan. 4, 1932	3.15	63.00	Porto Ricos.
" 7	3.135	62.70	Philippines, 3.10; Cubas, 3.17.
" 8	3.1733	63.47	Philippines, Porto Ricos, 3.15; Cubas, 3.17, 3.20.
" 9	3.20	64.00	Cubas.
" 12	3.165	63.30	Cubas, Porto Ricos, 3.17; Porto Ricos, 3.16.
" 13	3.16	63.20	Porto Ricos.
" 14	3.155	63.10	Cubas, 3.16; Porto Ricos, 3.15.
" 15	3.145	62.90	Cubas, 3.15; Cubas, Porto Ricos, 3.14.
" 18	3.13	62.60	Porto Ricos.
" 19	3.11	62.20	Cubas, 3.12; Philippines, 3.10.
" 20	3.10	62.00	Porto Ricos, Philippines.
" 21	3.08	61.60	Cubas, Porto Ricos.
" 30	3.06	61.20	Cubas.
Feb. 1	3.045	60.90	Cubas, 3.05, 3.04.
" 2	3.02	60.40	Porto Ricos.
" 3	3.00	60.00	Porto Ricos.
" 5	2.965	59.30	Porto Ricos, 2.98, 2.97; Cubas, 2.96; Cubas, Philippines, 2.95.
" 6	2.94	58.80	Philippines.
" 9	2.92	58.40	Porto Ricos, 2.94; Cubas, 2.92, 2.90.
" 10	2.90	58.00	Philippines, Porto Ricos, 2.90.
" 11	2.94	58.80	Porto Ricos.
" 15	2.995	59.90	Porto Ricos, 3.00; Cubas, 2.99.
" 16	2.96	59.20	Cubas, 2.97; Philippines, 2.95.
" 18	2.975	59.50	Porto Ricos, 2.98; Porto Ricos, Philippines, 2.97.
" 19	2.955	59.10	Cubas, 2.97; Porto Ricos, 2.94.
" 20	2.92	58.40	Porto Ricos.
" 23	2.895	57.90	Cubas, Porto Ricos, 2.90; Cubas, 2.89.
" 24	2.88	57.60	Philippines.
" 27	2.865	57.30	Porto Ricos, 2.88, 2.85.
" 29	2.85	57.00	Philippines.
Mar. 2	2.86	57.20	Porto Ricos, 2.85; Philippines, 2.87.
" 3	2.855	57.10	Porto Ricos, Cubas, 2.86; Philippines, 2.85.
" 4	2.845	56.90	Porto Ricos, Philippines, 2.85; Porto Ricos, 2.84.
" 5	2.81	56.20	Porto Ricos.
" 9	2.795	55.90	Porto Ricos, Philippines, 2.81; Philippines, 2.80; Cubas, 2.79, 2.78.
" 10	2.77	55.40	Cubas, 2.79; Philippines, 2.75.
" 11	2.765	55.30	Cubas, 2.76, 2.77.
" 12	2.76	55.20	Cubas.
" 14	2.775	55.50	Philippines, 2.77; Porto Ricos, 2.78.
" 15	2.76	55.20	Philippines.